I

THE JOURNAL OF Agricultural Economics Research

United States Department of Agriculture

Economic Research Service

Articles

Book Reviews

Vol. 43, No. 1, Winter 1991

This periodical is published quarterly. Subscription rates are: 1 year, $8; 2 years, $15; 3 years, $21. Non-U.S. orders, please add 25 percent. Send check or money order (payable to ERS-NASS) to:
ERS-NASS
P.O. Box 1608
Rockville, MD 20849-1608
or call 1-800-999-6779. This periodical is also available from the U.S. Government Printing Office—(202) 783-3238.

The Secretary of Agriculture has determined that the publication of this periodical is necessary in the transaction of public business required by law of this Department. Use of funds for printing this periodical has been approved by the Director, Office of Management and Budget.

Contents

In This Issue

"An idea whose time has come" is a familiar expression in the realm of policy. It means that a plan or program has become the embodiment of some theoretical notion surfacing at the right time. In the words of J.M. Keynes, "The ideas of economists and political philosophers, both when they are right and when they are wrong, are more powerful than is commonly understood. Indeed, the world is ruled by little else. Practical men, who believe themselves to be quite exempt from any intellectual influences, are usually the slaves of some defunct economist." Great ideas may go dormant for lack of champions, then flower again when new needs arise. As these needs arise how do those who discover and store ideas make them available? The ancillary question to writers and readers of journal articles is: to whom, for whom are journal articles addressed—how are the recorded and stored ideas contained in journals used by policy advisers, policy engineers, and policymakers?

Otto Doering's essay on institutions, individuals, and precedents in agricultural policy contains some notable illustrations of the history of economic ideas. He notes how Chester Davis and Howard Tolley influenced agricultural policy through the landmark 1940 Yearbook of Agriculture. He relates Rexford Tugwell's concepts of the 1930's to the PIK program of the 1980's. Doering questions the appropriateness of marginalist thinking for institutional reconstruction, but probably would concede that marginalist economics has been helpful in understanding how existing institutions and policies function. For an example of good integrative policy analysis, he cites Vincent and Eleanor Ostrom's public choice research. Mostly, Doering seems to be saying that to fully comprehend the role of economic ideas in policy, one must comprehend the institutional environment, the historical precedents, and the personalities.

Vollrath and Johnston extend some of the recent arguments of one of the original problems of classical economics—the relationship between trade and growth. More specifically, they challenge the simple dichotomy of developed countries with manufactures and underdeveloped countries with primary industries by presenting a model of eight sectors and five development classes. With their refined model, they examine trade as a means to exploit comparative advantage, showing that trade is favored in agriculture for middle-income countries but not for high-income and low-income countries. High-income countries are best served by importing light manufactures, and upper-middle and high-income countries have a per capita income gain from exploiting their comparative advantage in the finished capital goods industry, which commands highly skilled labor.

Canning examines the idea of benefiting producers who participate in the Conservation Reserve Program. He includes under producer welfare the payments to farmers and owners for warehousing their erodible acres, reducing income risks, and increasing prices from reduced commodity production. Canning analytically and empirically demonstrates welfare gains in the form of enhanced land values. Clearly there is gain to farmers and landowners, at least in the short run, but whether society gains is another issue.

Seldon and Hyde studied welfare gains from public investment in wood preservatives research. They conclude that such research produces net gains that are socially beneficial. But, internal rates of return to the industry are insufficient to be profitable, so the research investment on wood preservation will not likely be made by private industry.

Kott says that economists and statisticians differ in their view of linear regression from sample survey data. Economists want to model reality and use statistical tests to reject or not to reject their hypotheses. Statisticians want to describe characteristics of a population without counting all members of the population. He reviews two standard computer packages for doing regressions and estimating variances, and explains a modification of the statistician's design-based estimators that more nearly satisfies the economist's view.

Book reviews in this issue include Lewandrowski's generally supportive comments on the important work on forestry by Sedjo and Lyon. They have employed what Lewandrowski calls the first economic model of the world timber supply, a series of 50-year simulations. They conclude that there is no foreseeable shortage of timber. The analysis incorporates the shift from "gathered" old growth to economically managed forest production.

Wilson, who is with Forestry Canada, reviews Cohn's book on Canadian-American trade relations. He describes the book as Galbraithian in approach, a contribution to the political economy of agricultural trade. The book's focus on wheat as a proxy for Canada-United States trade is a shortcoming. However, Wilson appears to find enough information in the book to spark an interest in readers.

Morgan reviews Sandrey and Reynolds on *Farming Without Subsidies: New Zealand's Recent Experience*. New Zealand in 1984 went cold turkey on deregulation and trade liberalization, and that experience has been detailed in the well-integrated compilation of papers.

The reforms apparently landed harder on agriculture than on other sectors. Morgan lauds the effort that went into the book, but the experience of New Zealand may not provide a clear guide to larger, developed economies.

Vandeman describes Mann's *Agrarian Capitalism in Theory and Practice* as grounded in classical Marxist theory. Mann's thesis: there is inadequate recognition of the unique natural features of agricultural production, which, in turn, determines the social organization of agriculture. The approach is interdisciplinary. Vandeman recommends the book to readers who tire of placing the market at the center of the universe.

Within the pages of our social science literature, there are, no doubt, many ideas suitable for framing agricultural policy. Some of those ideas may be in this issue. However, the task of writers and readers of technical literature who wish to contribute to policies and programs is to fashion prescriptions that are readable and appealing to a much wider audience than we service here. If you are such a communicator, you must find a suitable medium or prepare for a Keynesian wait.

Gene Wunderlich

Looking Back While Going Forward: An Essential for Policy Economists

Otto Doering

Institutions, individuals, and historical precedents have always been important in economic policy decisions, but economists seldom adequately reflect these influences in their conventional economic analysis of policy. It seems that economists' deepening lack of cognizance of society's broader objectives means they seldom try policy instruments that are really new.

Other Paradigms

A number of social scientists have developed different approaches which analyze public policy. Institutional economists, historians, and political scientists began with descriptive analyses, developing their own premises, analytical systems, and predictive assumptions. Economists have allowed their own concern for increasing quantification and precision to narrow their focus, taking economics away from its roots in the broad social science view of political economy. Public choice analysis has recently provided a halfway house for economists because of its similar approach and many familiar assumptions.

Economists have compensated in different ways for the divergence from the other social sciences. One methodological alternative open to economists is to modify another social science and attempt to incorporate it within the economics paradigm. Recent efforts analyzing welfare-transferring policies and social welfare-increasing policies are good examples.

Incorporating modifications from other social sciences is attractive because problems are sliced in a way that economists can understand and trust, making such an approach a familiar and more user friendly one. Economists can apply a degree of mathematical rigor to this approach, folding something like public choice analysis into the analytics of neoclassical economics. Causality becomes clearer, capable of being demonstrated in the familiar terms of the economics paradigm. Such adaptations, however, keep the analytical scope narrow.

Other alternatives are public choice, political science, or historical analysis without adaptation. This route gains breadth but poses special difficulties for economists. It forces them into incompatible situations. Economists must integrate information on variables that differ from those in conventional economic models, and the two types of information do not always merge easily or conveniently.

In a sense, it is far easier to take the first alternative, concentrate on those variables in other approaches that economists tend to use themselves, and do so in a way that meets economists' notions of consistency. However, my gut feeling is that by forcing other approaches into the economists' box, we lose the strength of the other approaches that we sought in the first place.

We gain a great deal from approaching institutions, events, and behavior as students of institutional economics, history, political science, and public choice. Such an approach helps us understand better how to define policy problems as well as why government acts and when and why people respond to government. Alexis de Tocqueville's *Ancien Regime*, for example, contained heretical (but telling) comments on the impact of institutional structure upon the scope, process, and content of government policy after the French Revolution.[1] He showed how the inherited institutions of the centralized monarchy influenced the new French Republic to behave like its predecessor. Somewhat the same could be said more than 100 years later about the behavior of Russia under Lenin and Stalin following Czarist patterns of political control and economic development.

In contrast to the long-term influence of old institutions, something very different happened in France after the Second World War when effective policymaking occurred only with the creation of new institutions that broke the pattern of their predecessors. Students of comparative government followed the post-war metamorphosis of the French republics with fascination. As in the pre-war period, government after government would crash, unable to cope with national needs. DeGaulle waited in the wings until an institution was created with enough central power to allow the executive and the legislative branches to function effectively. DeGaulle's unwillingness to step into the void until institutions stabilized helped force the creation of such an institution. Effective institutions for decisionmaking and policy implementation were the major forces in determining what was possible and what happened in France, not economic influences as economists now measure them.

Economists cannot ask the right questions about the expected success or impacts of a policy unless they have some appreciation for the other forces at work. This view is stated superbly by Lionel Robbins in his

---

Doering is a professor of agricultural economics at Purdue University, West Lafayette, IN. He thanks Deborah Brown and Gene Wunderlich for their helpful reviews and Wayne Rasmussen for his sense of agricultural history.

[1]Literature cited in the text is listed in the Bibliography section at the end of this essay.

lecture on "Economics and Political Economy." Some of these forces were once within the ken of political economy but are no longer a part of modern economics. Broad macroeconomic policy analysis suffers as a result.

On a somewhat different level, some of the most helpful public choice analysis includes economic considerations, but economic paradigms are not necessarily the driving force of the analysis. A good example of this is the work of Robert Bish and Vincent and Eleanor Ostrom who come from the government and public administration tradition. They investigated numerous factors that affect the choice of public services and their delivery mechanisms. Their research in public administration led to fresh treatment on many issues of interest to economists—like the identification and analysis of noneconomic factors influencing the cost and quality of public services.

Insightful noneconomics approaches need not be wedged into the economics paradigm to be useful to economists. I am convinced that economists must review and learn from the other approaches, but it is not essential (and may be harmful) to force others' methods into the economist's mode.

Time Frame and Scope Limitations

Economists impose both time frame and perspective limitations on themselves. Current agricultural policy appears to be the product of 5-year flashbacks. Each of the recent farm bills tries to deal with the problems of the previous 5 years. When the environment cooperates, the bill works moderately well. When there is a major change in conditions, Congress has to act again. The process is one of tinkering with existing mechanisms without much discussion of new societal goals or the possibility of a changing environment.

Agricultural policy instruments were mostly forged in the 1930's in response to the cataclysmic events of the Depression. The events of the 1920's and 1930's led to a willingness on the part of the New Dealers to try almost anything. If something did not work, it was jettisoned without ceremony, and something else was tried. Henry A. Wallace, the most politically powerful Secretary of Agriculture under President Franklin D. Roosevelt, ran a free-wheeling show that would have made the White House staff of any recent administration blanch. Little micromanagement of USDA came from the White House, and not much supervision flowed from the secretary's office to the rest of the Department. Apparently Roosevelt was willing to give a number of strong-willed people their head, reining them in only when complete disaster loomed. Wallace did some of the same during his 1933-40 tenure at USDA. This attitude was encouraged by a sense of political self-confidence that lasted until Democrats suffered severe losses in an interim congressional election. Opposition to change within government was confined to the small entrenched bureaucracy originally in place. The larger, newly created bureaucracies and institutions initially owed their existence and growth to promoting and implementing change. The policies possible under such circumstances differ radically from policy possibilities today. There is not the national sense of urgency about today's major national fiscal and financial problems that would be necessary to overcome the resistance of today's entrenched bureaucracy. This inaction also limits scope.

Ones Who Looked Forward

During the 1930's, economists with a broad view of agricultural policy were able to create their own program options, anticipating with uncanny accuracy the situations we face today. It is a unique experience for an economist today to read the *1940 Yearbook of Agriculture*, which was the social science yearbook of the Wallace era. Chester Davis's piece on the development of agricultural policy since the end of the First World War sets the stage like an operatic overture. He reminds us that "a nation's agricultural policy is not set forth in a single law, or even in a system of laws dealing with current farm problems. It is expressed in a complexity of laws and attitudes which, in the importance of their influence on agriculture, shade off from direct measures like the Agricultural Adjustment Act through the almost infinite fields of taxation, tariffs, international trade, and labor, money, credit and banking policy" (p. 325). Davis's broad and wise perception was not well remembered, to our cost, in the 1970's with respect to trade, and in the 1980's with respect to money, credit, and banking policy. Davis's candor on issues like the usefulness of parity price or parity incomes as measures of appropriate levels of income support is remarkable. He wonders "whether the objectives of agricultural policy can be once and for all established by a simple exercise in arithmetic" (p. 320).

Howard Tolley's piece in the same *Yearbook*, "Some Essentials of a Good Agricultural Policy," is both prescriptive and prophetic. He asks what farm people want in terms of a good life and defines these wants and their sources. Then he tries to determine policies that would best meet those wants, while taking into account the broad pattern of policy shaped by these wants during the previous decade. Tolley saw the objectives of farm policy during his era to be of three general types:

- "Activities designed to increase incomes of farmers who produce commodities for sale on a commercial scale;
- The efforts to raise incomes and to improve the living conditions of migrant laborers, sharecroppers, subsistence farmers, victims of drought or flood, and others at a disadvantage

within agriculture itself; and

- Activities designed to encourage better land use and more efficient production."

Tolley wrote that "most government programs of both the distant and the recent past have been directed toward improvement in the condition of commercial agriculture. It appears now [1940] that the last two of the groups of activities just listed will receive increasing attention in the immediate future" (p. 1,169).

The remarkable thing about agricultural policymakers in the 1930's was that they were not marginalists in their thinking. The severe nature of the problems confronting them and the inability of existing institutions and policies to cope with these problems encouraged an intellectual clean slate with a willingness (at times, propensity) to develop new approaches and new institutions. Some of Rex Tugwell's social experiments with the Resettlement Administration would be considered radical even today. (Tugwell was staff economist undersecretary to Wallace and head of the Resettlement Administration under Franklin Roosevelt.) The change that swept through the U.S. Department of Agriculture was such that many activists and visionaries believed that USDA was where the coming social revolution in America would originate.

Looking years ahead and recognizing the importance of resource conservation, Tolley suggested tying program participation to requiring farmers to "follow a system of farming that will more fully conserve the soil or control erosion than does their present system" (p. 1,175). He also recognized the continuing exodus of farm people to urban areas, its impacts, and its potential policy requirements. These architects of new programs did not see mere tinkering at the margin as sufficient to meet present needs, let alone the future goals of farm and urban people regarding agriculture and public welfare.

Marginalists in Objectives and Policies

A critical question today is whether policy economists are now marginalists, by natural selection if not by training. Is the discipline of economics, as we practice it and teach it, largely marginalist? It is not necessarily a bad thing to be a good marginalist. But, at times, our view of what is possible or appropriate for analysis or policy must be broader. For some past generations of economists, the paradigm, the profession, and the political system allowed them to be more than marginalists, especially in times of crisis.

Many persons are concerned about the paucity of new ideas from policy economists. These observers are asking us to cast a wider net in terms of both goals and policies for agriculture, natural resources, and the public welfare. Current agricultural and rural policies appear to have reached the end of the line in terms of public support, available finance, favorable international terms of trade, and a politically supportable agricultural structure and income distribution. It is not just fate that has caused agricultural program expenditures to be cut 25 percent in the budget compromise of 1990, a much greater proportional hit than any other major program.

Are we looking at continuing marginal changes in agricultural policy and agricultural policy mechanisms, or are we thinking ahead for basic structural changes in both policy and policy mechanisms? Mechanisms aside, how broadly is agricultural policy viewed? Should agricultural policy support *all* farmers regardless of their size and income levels, their environmental and conservation practices, their use of resources (especially subsidized resources like water), or their treatment of migrant labor? Are we continuing to craft farm programs to meet the first goal mentioned by Tolley, "activities designed to increase incomes of farmers who produce commodities for sale on a commercial scale," to the point where this objective by itself is no longer well supported by the general public? Are policy economists just marginalists looking narrowly at single-sectional goals rather than at the breadth of society's goals?

Tolley believed in 1940 that the first goal for agriculture had been sufficiently dealt with. We attempted to address the second goal in the Great Society programs and recently addressed the environmental and conservation concerns in the context of commercial farming policy. At what point should policy economists initiate a broader debate on goals for agriculture and rural people? Fresh and innovative thinking about where we go from here will have to go beyond current policies and their mechanisms and beyond marginal analysis. Marginalists survive well during stability. We are beyond stability, and instability demands something else.

Preparing for an Unstable World

What do those charged with agricultural policy do if the GATT negotiations continue to founder upon agricultural issues, trade wars break out, the United States has a prolonged recession, deficit and financial institutions continue to deteriorate, problems intensify, we continue to sell off productive assets to foreign firms, and all this leads people to believe that economic nationalism is the best approach to deal with our declining world economic power? Is commercial agricultural policy all we really need for agriculture and rural America? Do we finally pay real attention to the broader national policies Davis recognized as being fundamental to agriculture? Is anyone worried about this? Who has been thinking about more than marginal changes in existing policy and institutions to deal with such events?

Policy economists need to do good economics. They also need to be aware of what is going on beyond the economics paradigm. We cannot afford to be methodologically, intellectually, or politically bound in any way that narrows our approach to problem definition or problem solving. Today, the confines of institutional environment, training, intellectual scope, and methodology inhibit economists from exploring a sufficiently wide range of alternative policies and their consequences.

An interest in institutions and their influence, the study of individual and group behavior, and a knowledge of history force an economist to come to grips with things that go beyond marginal analysis. Recent world political and military events have been cataclysmic, not marginalist. This says that robust methodological approaches in economics that can reflect basic structural changes are more important than superior analytical performance that assumes stability. In addition, if we consider noneconomic investigations of human actions only to squeeze them into the economics paradigm, we will forfeit that very breadth and scope economics needs. An increasingly volatile world will require better understanding of fundamental human and institutional behavior. Investigations beyond economics must be used to broaden our perspective and enhance our view beyond the economics paradigm.

Bibliography

Bish, Robert, and Vincent Ostrom. *Understanding Urban Government: Metropolitan Reform Reconsidered.* American Enterprise Institute, Washington, DC, 1973.

Ostrom, Vincent, Robert Bish, and Eleanor Ostrom. *Local Government in the United States.* New York: ICS Press, 1988.

Ostrom, Vincent. *The Intellectual Crisis in American Public Administration.* Tuscaloosa: University of Alabama Press, 1989.

Peek, George. *Why Quit Our Own.* New York: Van Nostrand, 1936.

Rausser, Gordon C., and William E. Foster. "Political Preference Functions and Public Policy Reform," *American Journal of Agricultural Economics.* Vol. 72, No. 3, Aug. 1990, pp. 641-52.

Robbins, Lionel. "Economics and Political Economy," *American Economic Review.* Vol. 71, No. 2, May 1981, pp. 1-10.

Tocqueville, Alexis de. *The Old Regime and the French Revolution.* New York: Doubleday, Anchor Books, 1978.

U.S. Department of Agriculture. "Farmers in a Changing World," *1940 Agricultural Yearbook*, 1940.

The Influence of the Commodity Composition of Trade on Economic Growth

Thomas L. Vollrath and Paul V. Johnston

Abstract. *Empirical evidence supports the proposition that national income growth is strongly affected by trade specialization and comparative advantage in eight economic sectors. Commercial policy distortions and factor intensity reversals explain why trade does not always fit the skilled labor continuum underlying sectors ranked along the ladder of development. Income elasticities with respect to openness imply that economies become less dependent on international markets as they grow. This article examines the effects of the commodity composition of trade on economic growth, going beyond previous analytical efforts investigating international trade and domestic growth linkages.*

Keywords. *Economic growth, comparative advantage, development ladder, growth-producing sectors.*

The engine of economic growth during the 19th century was thought to be fueled by trade and industrial growth. Trade, viewed as an engine, served simply to transmit growth impulses from developed to developing countries (*19*).[1] This trade engine hypothesis has been criticized because it falsely dichotomizes the world into developed countries, which produce and export industrial manufactured goods, and the developing countries, which produce and export primary products (*24*). In fact, agricultural exports as well as manufactured goods are an important source of revenue for many developed countries. Moreover, developing countries have diversified their export portfolios beyond primary commodities to include manufacturing, an increasingly important source of foreign exchange.

Most econometric studies that examine the influence of trade on economic growth have sought more sophisticated explanations than that provided by the simple trade engine hypothesis (*1, 2, 3, 4, 10, 15, 20, 21, 22, 23, 27*). These studies seem to provide persuasive evidence for linking domestic economic growth to international trade.[2] Most restricted attention to exports. Some, however, focused exclusively on the newly industrializing or semi-industrial countries (*4, 10, 27*). Excluding imports ignores half of the trade linkages affecting growth. Basing conclusions upon analyses of data restricted to the more successful developing countries limits the ability to draw generalizations that are relevant to all countries.

Other studies have dissected the relationship between trade and growth by using an accounting framework. Kavoussi (*14*) explains country-trade performance in terms of such factors as competitiveness, diversification, and world demand. His analysis shows that rapid expansion of export earnings requires both favorable external markets and outward-oriented commercial policies. Kavoussi concludes that when world demand is strong, the benefits accruing to developing countries having liberal trade policy regimes (for example, improved allocation of resources, enhanced factor productivities, realization of scale economies, and accumulation of additional capital) clearly outweigh the dangers (possible deterioration in terms of trade, tariff and nontariff restrictions impeding trade flows, and slow growth in the demand for developing-country commodity exports). But, his findings suggest that when external demand is weak, the gains from outward-oriented policies are somewhat offset by their negative effects.

Singer and Gray (*25*) extend Kavoussi's analysis by differentiating among developing-country regions. They show that the correlation between outward orientation and growth under favorable market conditions is relatively weak for the low-income countries. They also show that, in the low-income countries, the gains from openness are offset by its negative effects when external demand is weak.

Decomposition analyses, based upon accounting formulae, leave much to be desired. They provide little information about the cause-and-effect relationships among economic determinants. In this study, we combine the econometric and decomposition traditions in examining linkages between trade and income growth. We contend that the trade-growth relationship is not merely determined by trade policies and world economic conditions (as suggested by Kavoussi and Singer and others), but is also affected by comparative advantage. The role trade can play in inducing economic growth critically depends upon countries' exploiting their comparative advantages. The trade-growth nexus is, therefore, dependent upon global competition and specialization patterns.

Vollrath and Johnston are agricultural economists with the Agriculture and Trade Analysis Division, ERS. The authors thank Andrew Hamilton, Sharlan Starr, and Mary Wright for their statistical assistance working with the United Nations' Trade Net Data System.

[1]Italicized numbers in parentheses cite sources listed in the References section at the end of this article.

[2]However, some development economists have questioned whether some basic level of development is necessary before a country can benefit from trade-oriented growth. Michaely (*20*) observed "that the positive association of the economy's growth with the growth of the export share appears to be particularly strong among the more developed countries, and not to exist at all among the least developed." Chenery (*9*) believes that the greater role of trade in explaining growth is one of the features that distinguishes developing from developed countries. Helleiner (*12*) contends that there is "no evidence to support the proposition that the degree of export orientation is associated with growth performance either in Africa or in poor countries elsewhere."

We examine the relationship between income at various levels of development and country-trade competitiveness patterns across economic sectors. Our approach is a source of growth equation that concentrates on trade determinants thought to affect income differentials and economic growth.

There are six country classifications,[3] five of which are differentiated by the level of development, and the sixth is an oil export group (OPEC). We look at both low-income (LIC) and high-income (HIC) countries as well as three intermediate groups—the upper low-income (ULIC), middle-income (MIC), and upper middle-income (UMIC) countries.[4] Following the Heckscher-Ohlin factor abundance theory, we categorize commodities on the basis of what is known about production processes. Commodities with high substitution elasticities are aggregated into eight economic sectors because they embody similar factor requirements.

Dynamic Comparative Advantage and the Stages Approach to Development

According to the stages approach to development and dynamic comparative advantage, the composition of a country's trade will change in response to changing relative factor endowments. Such change is associated with movement up the ladder of economic development.[5] Countries climb this ladder as they accumulate additional physical and human capital per worker. Low-income countries, situated on the lowest rung of the development ladder, tend to specialize in the production of commodities that intensively use their relatively abundant unskilled labor. As these countries develop, they move progressively to higher rungs, corresponding to increasingly skilled labor.

Bowen (*7*), examining relationships between changes in national resource endowments and changes in the composition of a country's trade structure, found them to be consistent with the dynamic factor proportion explanation of trade.

Here, we identify three primary sectors (agriculture, mining, fish and forestry) as well as five manufacturing sectors: high technology, finished capital goods, intermediate differentiated goods, basic intermediates, and agriculturally linked industries (table 1). These economic sectors, and especially the five manufacturing sectors, symbolize a ladder of development because of their varying needs for skilled labor. At the bottom manufacturing rung are the agriculturally linked industries, which use substantial semi-skilled labor relative to other inputs. Next come intermediate differentiated goods and basic intermediates. These two sectors depend upon moderately skilled labor. The top two rungs—finished capital and high-tech industries—require skilled and highly skilled labor.

The Econometric Accounting Model

Our theoretical model examines the extent to which income growth, at different stages of economic

Table 1—Sketch of eight economic sectors: Input-output descriptions

Sector	Typical industries	Factor intensity requirements
High technology	Medical products, optical and medical instruments, telecommunications equipment, organic and inorganic chemicals	Highly skilled labor
Finished capital goods	Automobiles, trucks, buses, boats, ships, aircraft, argicultural machinery, war firearms	Skilled labor and capital
Basic intermediate goods	Iron and steel, electrical energy, processed petroleum and coal, paper, fertilizer, rubber, plastic	Moderately skilled labor and capital
Intermediate differentiated goods	Office supplies, maps, musical instruments, hunting and sporting equipment, watches, clocks, plumbing, heating and lighting equipment	Moderately skilled labor
Agriculturally linked industries	Textiles, yarn, fabrics, clothing, leather, footwear, furniture	Semi-skilled labor
Mining	Unprocessed coal and petroleum, crude fertilizer, natural gas, metalliferous ores	Unskilled labor and natural resources
Fish and forestry	Fish and fish preparations; wood, lumber, and cork; pulp and waste paper	Unskilled labor, and natural resources
Total agriculture	Food and live animals; beverages and tobacco; animals and vegetable oils	Unskilled to moderately skilled labor, land, and capital

Source: Data were obtained from the U.S. Trade Net System, National Institutes of Health, Bethesda, MD.

[3]Research is underway to isolate the impact of country movement from one income category to another.

[4]The LIC include Burkina Faso, Ethiopia, Ghana, India, Kenya, Madagascar, Malawi, Niger, Senegal, Sudan, and Togo. The ULIC include Bolivia, Cameroon, Egypt, El Salvador, Honduras, Morocco, Pakistan, Philippines, and Sri Lanka. The MIC include Colombia, Costa Rica, Dominican Republic, Guatemala, Jordan, Nicaragua, Paraguay, South Korea, Thailand, Tunisia, and Turkey. The UMIC include Brazil, Chile, Greece, Ireland, Israel, Italy, Malaysia, Mexico, Portugal, South Africa, Spain, Syria, Trinidad, and Uruguay. OPEC includes Algeria, Gabon, Indonesia, Iran, Kuwait, Nigeria, Saudi Arabia, and Venezuela. The HIC include Australia, Austria, Canada, Denmark, Finland, France, Iceland, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom, United States, and West Germany.

[5]Balassa (*3*) concluded that the prospects of economic growth through exports appear much brighter once we understand the character of the changing pattern of comparative advantage because developing countries replace each other as they move up the comparative advantage continuum.

development, is affected by trade specialization patterns, government intervention, and world economic conditions:

$$y^* = f(wc, op, CA),$$

where:

y^* = real per capita income;
wc = global economic conditions;
op = government intervention; and
CA = vector of comparative advantage.

We define global economic conditions as the real value of world exports. We use Johnston's (*13*) openness index (op) as a proxy for government intervention:[6]

$$op = 1/(1+E/T),$$

where E is the total domestic production consumed at home (consumption plus investment plus government expenditures minus imports) and T is total (exports plus imports).

The CA vector needs some elaboration. Balassa (*5*) became pessimistic about identifying comparative advantage and explaining trade on the basis of a few general principles derived from various explanations of international trade found in the theoretical literature. Moreover, he questioned the usefulness of explicitly accounting for all the influences affecting trade since comparative advantage is the outcome of so many factors, "some measurable, others not, some easily pinned down, others less so." As a practical alternative, Balassa suggested that comparative advantage be "revealed" through examination of country/commodity trade patterns because actual trade "reflects relative costs as well as differences in nonprice factors."

The focus on broad economic sectors in this study entails tracking both exporting and importing behavior. We, therefore, use Vollrath's (*29*) revealed competitiveness (RC) index to measure comparative advantage because it accounts for such two-way trade. RC[7] is defined as follows:

$$RC^{i,r}_{a,n} = \mathrm{Ln}\{[(XS^i_a/XS^r_a)/(XS^i_n/XS^r_n)]/[(MD^i_a/MD^r_a)/(MD^i_n/MD^r_n)]\},$$

where XS refers to exports, MD to imports, subscript *a* to any particular sector, subscript *n* to a commodity composite aggregate consisting of all other sectors, and superscripts *i* and *r* to the home country and to the rest of the world, respectively.

[6]Johnston's index is strictly monotonic and bounded by zero and one, unlike alternative measures of openness used by Leamer (*18*) and Kravis, Heston, and Summers (*17*). Zero defines autarky. One defines perfect dependency in which all goods produced at home are exported and all domestically consumed goods are imported.

[7]A positive value for revealed competitiveness indicates that the country or region in question possesses a relative competitive advantage for the particular commodity being investigated. Conversely, a negative value indicates a relative competitive disadvantage.

RC is thought to be the most reasonable proxy of comparative advantage available (*28*). It is not, however, a perfect measure. To be precise, RC reveals relative competitive advantage and not real comparative advantage because it is based upon actual rather than optimal trade flows, the latter not being observable. When intrepreting the empirical results in the following section, it is important to keep in mind that RC's embody not just the economic determinants of comparative advantage but also relative distortions.

Leading and Lagging Sectors

Comparative advantages differ for countries at dissimilar levels of development, yet countries do not always exploit their natural advantages. To underscore the growth benefits of increased efficiency in resource use, we distinguish *leading* from *lagging* economic trade sectors. Leading and lagging sectors are determined by the positive correspondence between our theoretically based expectations concerning actual comparative advantage and the signs of the revealed comparative advantage coefficients generated by our empirical model. More specifically, a leading (lagging) sector is identified when we anticipate a country/sector comparative advantage (comparative disadvantage) and obtain a positive (negative) RC coefficient from regressing real per capita national income on revealed comparative advantage.

It is useful to make a distinction between changes in national and sector incomes and changes in revealed and actual comparative advantages. Enhancing revealed comparative advantage always generates additional income in the reference sector. But only increases in revealed comparative advantages that are consistent with increases in actual comparative advantage also augment national income. Likewise, decreases in revealed comparative advantage always diminish reference sector income. But such decreases actually increase overall domestic income if the reference sector is a comparative-disadvantage sector.

We rely upon economic theory and knowledge of the real world to identify expectations, summarized in table 2, about the chain of comparative advantage and the ladder of development as developing countries experience economic growth.

High-income countries are expected to have comparative advantages in the knowledge-intensive high-tech sector and in the capital- and skilled-labor-intensive finished capital goods sector. Upper middle-income countries are also expected to have comparative advantages in both of these areas because our broadly defined sectors include industries where well-established technologies have been transferred to countries possessing relatively inexpensive but highly skilled labor.

Table 2—Chain of comparative advantage and the ladder of development: Theoretical expectations[1]

Item	Low-income countries	Upper low-income countries	Middle-income countries	Upper middle-income countries	High-income countries	OPEC oil exporters
High technology	–	–	–	+	+	–
Finished capital goods	–	–	–	+	+	–
Basic intermediate goods	–	–	+	+	–	+
Intermediate differentiated goods	–	–	+	–	–	–
Agriculturally linked industries	–	+	+	–	–	–
Mining	+	+	–	–	+	+
Fish and forestry	+	+	+	–	–	+
Total agriculture	+	+	+	–	+	–

[1]The chain of comparative advantage is identified by pluses and minuses which indicate comparative-advantage (+) and comparative-disadvantage (–) sectors, respectively. The shaded area identifies a ladder of economic development.

OPEC, upper middle-, and middle-income countries are believed to have comparative advantages in the iron and steel complex and in similar resource-dependent industries. Such basic intermediates require capital and moderately skilled labor, resources these country groups have in relative abundance.

We contend that middle-income countries have comparative advantages in intermediate differentiated goods because countries at this moderate level of development commonly possess a relative abundance of moderately skilled labor, a resource that these goods use comparatively intensively. Expected comparative advantages in both middle- and upper low-income countries for the agriculturally linked industries sector is explained by the correspondence between relative input requirements and relative factor availabilities with respect to semi-skilled labor.

Countries at the low end of the development spectrum, specifically those in the upper low- and low-income categories, are expected to possess comparative advantages in primary sectors, such as fish and forestry, mining, and agriculture, where production can take place using unskilled and semi-skilled labor intensively. We also contend that middle-income countries have comparative advantages in both agriculture as well as fish and forestry because of the natural resource endowments characterizing this income category where virtually all countries have direct access to ocean fisheries, and most of them have relatively high land-to-labor ratios favoring agriculture. We believe that OPEC countries have comparative advantages in the two extractive sectors, namely mining and fish and forestry.

We contend that high-income countries have comparative advantages in agriculture because of the capital- (and sometimes land-) intensive technological structure of developed-country agriculture. And, we believe that the high-income countries have comparative advantages in mining because of the inclusion of mineral-resource rich countries, such as Australia, Canada, and the United States within this income grouping.

Econometric Findings

Table 3 shows the empirical results and table 4 identifies leading and lagging sectors. The fact that we obtained so many statistically significant RC coefficients[8] and that the preponderance of these coefficients are consistent with our *a priori* theoretical expectations underscores the importance of comparative advantage in determining international trading patterns.

Agriculture, which intensively uses unskilled labor in developing countries, is a leading sector for upper low-income countries and middle-income countries, and is an especially important source of foreign exchange for middle-income countries. Agriculture is also a leading sector in high-income countries, a not unexpected result given that worldwide agriculture is characterized by factor-intensity reversals.[9] Agriculture is a lagging sector in upper middle-income countries and OPEC. The policy implication of this finding is that taking resources out of agriculture and increasing imports of agricultural commodities would actually increase income growth in these two sets of countries.

The empirical results for the extractive sectors, mining and fish and forestry, were generally consistent with the stages approach to trade and development. Mining is a leading sector in low-income countries, upper low-income countries, and OPEC as well as high-income countries. Fish and forestry was a leading sector in low-income countries, middle-income countries, and OPEC and a lagging sector in high-income countries and upper middle-income countries.

Agriculturally linked industries are a leading sector for middle-income countries and a lagging sector for

[8]We restrict our attention only to those generated RC coefficients which have t-statistics that suggest a greater than 80-percent confidence interval.

[9]In contrast to developing-country agriculture, developed-country agriculture requires a more highly skilled labor force, relatively abundant capital, and in the case of Australia, Canada, and the United States, considerable land. Policies protecting domestic agriculture may also contribute to the positive relationship found in the developed countries between increases in agricultural RC's and increases in per capita income.

Table 3—Trade determinants of real per capita income in five income groups and OPEC countries[1]

Item	Low-income countries	Upper low-income countries	Middle-income countries	Upper middle-income countries	High-income countries	OPEC oil exporters
Intercepts	4.61440	.50854	–.73235	–1.05422	–.80708	2.86295
	(8.16)	(1.08)	(–1.29)	(–1.99)	(–3.54)	(1.85)
High technology	–.00005	.005414	.001168	.026268	–.002047	.018254
	(–.01)	(1.43)	(.27)	(5.56)	(–.73)	(1.72)
Finished capital goods	.003083	.005159	.002121	.000188	.008587	.005479
	(1.04)	(2.14)	(.60)	(.05)	(4.47)	(.91)
Basic intermediate goods	–.000353	.031920	–.009200	.010614	–.02535	.029372
	(–.12)	(5.53)	(–1.20)	(1.93)	(–9.79)	(2.04)
Intermediate differentiated goods	.002206	–.006432	.022913	.000159	.003110	.040375
	(.78)	(–1.60)	(5.12)	(.03)	(1.42)	(3.77)
Agriculturally linked industries	–.007270	–.007077	.053853	–.009648	–.033888	–.007977
	(–2.07)	(–1.67)	(10.68)	(–2.52)	(–8.78)	(–.74)
Mining	.015569	.013105	.001878	–.001326	.017298	.119446
	(4.27)	(2.94)	(.72)	(–.40)	(9.14)	(5.33)
Fish and forestry	.012284	–.017825	.006135	–.034094	–.021903	.012021
	(4.45)	(–3.66)	(1.79)	(–10.06)	(–12.14)	(1.33)
Total agriculture	–.000617	.018279	.043609	–.033296	.010568	–.055972
	(–.09)	(2.83)	(6.02)	(–6.02)	(4.33)	(–3.24)
Government intervention	.005852	–.000155	.002782	.001221	.000519	.009337
	(11.14)	(–.53)	(4.37)	(3.97)	(2.48)	(6.54)
Global economic conditions	.061143	.310701	.384396	.442101	.466789	.182476
	(2.27)	(13.85)	(14.15)	(17.38)	(42.45)	(2.52)

Note: $Ln[y^*_{jk(j)t}] = \beta_{0j} + \Sigma_i^8 \beta_{ij} Ln[RC_{jk(j),i}] + \beta_{9j} op_{jk(j)t} + \beta_{10j} Ln[wc_{jk(j)t}] + \mu_{jk(j)t}$, where:
i = agriculture, fish and forestry, mining, agriculturally linked industries, intermediate differentiated goods, basic intermediates, finished capital goods, and high technology;
j = LIC, ULIC, MIC, UMIC, OPEC, HIC;
k_j = country in group j; and
t = 1966, ... 1985.

[1]The t-values appear in parentheses beneath the regression coefficients. A times-series, cross-country statistical program that corrects for serial correlation, heteroskedasticity, and contemporaneous correlation was used to estimate the coefficients.

Table 4—Leading and lagging sectors[1]

Item	Low-income countries	Upper low-income countries	Middle-income countries	Upper middle-income countries	High-income countries	OPEC oil exporters
High technology				+		(+)
Finished capital goods		(+)			+	
Basic intermediate goods		(+)		+	–	+
Intermediate differentiated goods		–	+			(+)
Agriculturally linked industries	–	(–)	+	–	–	
Mining	+	+			+	+
Fish and forestry	+	(–)	+	–	–	+
Total agriculture		+	+	–	+	–

[1]With the exception of signs in parentheses, pluses and minuses refer to leading and lagging sectors, respectively. All pluses (minuses) indicate statistically significant, positive (negative) relationships between national income and revealed competitive advantage. Blank cells identify statistically insignificant results.

high-income countries, upper middle-income countries, and low-income countries. Middle-income countries clearly benefit from being suppliers of such semi-skilled labor-intensive light manufactures as textiles, shoes, and furniture. The middle-income category is the only country category with a positive income elasticity with respect to revealed comparative advantage in agriculturally linked industries, and this elasticity (0.054) is comparatively very strong. As evidenced by the magnitude of corresponding negative elasticities, the high-income countries have the strongest interest in importing light manufactures, followed by upper middle- and low-income countries.

The econometric results also show that intermediate differentiated goods is a leading sector for middle-income countries and a lagging sector for upper low-income countries. By moving further up the commodity chain of comparative advantage, we find that a source of growth for OPEC, upper low-income countries, and upper middle-income countries occurs in being competitive in such basic intermediate goods as

processed petroleum and coal and iron and steel production, industries that require considerable capital and moderately skilled labor. The only trade theory misfit among these groups is upper middle-income countries.[10]

Finished capital and high technology were leading sectors in upper middle-income countries and high-income countries, respectively. That high technology is a leading sector in upper middle-income countries, and not in high-income countries, is not really surprising given the relatively high level of aggregation in defining this sector, suggesting that the domestic supply (demand) for high-tech products outstrips domestic demand (supply) in the upper middle-income countries (high-income countries). The results affirm Vernon's product cycle explanation of trade, which says that the mass production of new innovative products is quickly transferred (especially in today's increasingly integrated international capital market) to countries possessing less highly skilled labor than in originating countries. These transfers often occur as multinational corporations seek foreign sources of cheap but relatively well-educated labor. Even though the profits of such investments are partially transmitted to the home country, high-tech commodity exports are recorded on the national account registers of producing countries.

With exceptions in the OPEC and upper low-income countries country groupings, the statistically significant RC coefficients conform with our expectations derived from trade and development theory. But, increased RC's in the high-tech and intermediate differentiated goods sectors augment national income in OPEC, contrary to the pure chain theory of comparative advantage. It is not inconceivable that OPEC has achieved real comparative advantages in these two sectors by targeting specific industries for large subsidies, resulting in the accumulation of human and physical capital.

Unlike OPEC, developing countries can ill afford misallocating resources. Yet, the probability of mismanagement is especially high among upper low-income countries because many of their decision-makers evidently believe in the efficacy of state planning; advocate self-sufficiency, industrialization, and import substitution; and distrust international market mechanisms.[11] Biased interventions that squeeze returns from comparative-advantage sectors induce resource flight, reducing efficiency and income in the overall economy.[12]

Our empirical results suggest that upper low-income countries favor both heavy industry and sophisticated manufacturing and discriminate against primary and simple manufacturing. ULIC per capita income varied inversely with RC's for fish and forestry and the agriculturally linked sectors but varied directly with the finished capital goods and basic intermediates sectors.[13] We have insufficient information to determine how much national income would have increased had upper low-income countries pursued more market-oriented development strategies, permitting them to exploit their natural comparative advantages.

The two variables that represent commercial policy and world economic conditions generally supported our expectations. Oil-exporting countries come closest to being perfectly open. Perfect openness occurs when all domestic production is exported and all domestic consumption is imported. Not surprisingly, OPEC has the highest income elasticity with respect to the openness index than any other of our country categories.

Excluding OPEC, the income elasticities with respect to openness are positive, indicating that as economies become more open, per capita income increases. The openness elasticities, however, are inversely related to the level of development. This rank order suggests that domestic income growth is less (more) dependent upon the international market, the higher (lower) the level of economic development. The exception to this generalization is the upper low-income countries. Here again, we have evidence that these countries are not reaping growth dividends from participating in global markets, most likely due to their adoption of inward-oriented development strategies. The pursuit of self-sufficiency and balanced internal growth appears to have a high opportunity cost.

The responsiveness of domestic income growth to global economic conditions is generally directly related to the level of development. Economists have observed that the relative importance of differentiated products in a country's trade bundle increases as one moves from low- to middle-income countries, from middle- to upper middle-income countries, and from upper middle- to high-income countries. In addition, we know that the income elasticities of demand for differentiated products are usually higher than for undifferentiated and primary products. The magnitudes of the coefficients for global economic conditions across income groups, therefore, seem reasonable. Incomes in high-income countries, outside of OPEC, rise (fall) more than those in low-income countries during global economic upswings (downswings).

Conclusions

This article continues the discussion about the influence of trade on economic growth by adding greater

[10]The drive toward industrialization in many developing countries entailed the adoption of import-substitution development strategies. Widespread implementation of this strategy may explain why basic intermediate goods became such an important source of national income growth for upper low-income countries.

[11]The World Bank (*29*) considers all countries within our upper low-income country category as being inwardly oriented, with the exception of Egypt and Morocco, two countries they did not classify.

[12]Our openness measure does not adequately capture all aspects of government intervention.

[13]Were RC's unadulterated measures of comparative advantage, these results would be surprising.

commodity and country detail than found in other studies, disaggregating the total economy into eight economic sectors, and classifying countries into five categories of real per capita income and an OPEC group.

Empirical evidence shows that: (1) trade-growth linkages often correspond to dynamic comparative advantage, (2) the makeup of commodity trade affects income growth, and (3) the composition of country trade patterns responds to shifts in relative factor endowments and movements up the income ladder.

We found that policy distortions and factor intensity reversals explain why trade does not always fit the skilled-labor continuum. Calculated income elasticities with respect to openness imply that economies become less dependent on international markets as they grow. Also, the influence of world economic conditions on economic growth is greater for high- than for low-income countries.

Improved indicators of commercial policy and development strategy are needed to assess the impact of government intervention more comprehensively.

References

1. Balassa, Bela. "Comparative Advantage in Manufactured Goods: A Reappraisal," *The Review of Economics and Statistics*. Vol. 68, No. 2, May 1986, pp. 315-19.

2. ______. "Exports, Policy Choices, and Economic Growth in Developing Countries After the 1973 Oil Shock," *Journal of Development Economics*. Vol. 18, 1985, pp. 23-35.

3. ______. "The Changing Pattern of Comparative Advantage in Manufactured Goods," *The Review of Economics and Statistics*. Vol. 61, No. 2, Aug. 1979, pp. 259-66.

4. ______. "Exports and Economic Growth: Further Evidence," *Journal of Development Economics*. Vol. 5, No. 2, 1978, pp. 181-89.

5. ______. "Trade Liberalization and 'Revealed' Comparative Advantage," *The Manchester School of Economic and Societal Studies*. Vol. 33, 1965, pp. 99-123.

6. Ballance, Robert H., Helmut Forstner, and Tracy Murray. "Consistency Tests of Alternative Measures of Comparative Advantage," *The Review of Economics and Statistics*. Vol. 69, No. 1, Feb. 1987, pp. 157-61.

7. Bowen, Harry P. "Changes in the International Distribution of Resources and Their Impact on U.S. Comparative Advantage," *The Review of Economics and Statistics*. Vol. 65, No. 3, Aug. 1983, pp. 402-14.

8. Chen, Tain-jy, and De-piao Tang. "Comparing Technical Efficiency Between Import-Substitution-Oriented and Export-Oriented Foreign Firms in a Developing Economy, *Journal of Development Economics*. Vol. 26, Aug. 1987, pp. 277-89.

9. Chenery, Hollis B. "Interaction between Theory and Observation in Development," *World Development*. Vol. 11, No. 10, 1983, pp. 853-61.

10. Feder, Gershon. "On Exports and Economic Growth," *Journal of Development Economics*. Vol. 12, 1982, pp. 59-73.

11. Havrylshyn, Oli, and Iradj Alikhani. "Is There Cause for Export Optimism? An Inquiry into the Existence of a Second Generation of Successful Exporters," *Weltwirtschaftliches Archiv*. Vol. 118, No. 4, 1982, pp. 651-63.

12. Helleiner, G.K. "Outward Orientation, Import Instability and African Economic Growth: An Empirical Investigation," *Theory and Reality in Development*. Sanjaya Lall and Frances Steward (eds.). New York: St. Martin's Press, 1986.

13. Johnston, Paul V. "Proposed Measure of Trade Dependency." U.S. Dept. Agr., Econ. Res. Serv., forthcoming.

14. Kavoussi, Rostam M. "International Trade and Economic Development: The Recent Experience of Developing Countries," *The Journal of Developing Areas*. Vol. 19, April 1985, pp. 379-92.

15. ______. "Export Expansion and Economic Growth: Further Empirical Evidence," *Journal of Development Economics*. Vol. 14, 1984, pp. 241-50.

16. Kravis, Irving. "Trade as a Handmaiden of Growth: Similarities Between the Nineteenth and Twentieth Centuries," *The Economic Journal*. Vol. 80, Dec. 1970.

17. Kravis, Irving B., Alan W. Heston, and Robert Summers. "Real GDP Per Capita For More Than One Hundred Countries," *The Economic Journal*. Vol. 88, June 1978, pp. 215-42.

18. Leamer, Edward E. "Measures of Openness." Working Paper No. 447. University of California-Los Angeles, Department of Economics, July 1987.

19. Lewis, W. Arthur. "The Slowing Down of the

Engine of Growth," *American Economic Review*. Vol. 70, No. 4, Sept. 1980, pp. 555-64.

20. Michaely, Michael. "Exports and Growth: An Empirical Investigation," *Journal of Development Economics*. Vol. 4, 1977, pp. 49-53.

21. Michalopoulos, C., and K. Jay. "Growth of Exports and Income in the Developing World: A Neoclassical View." AID Discussion Paper No. 28. U.S. Agency for International Development, 1973.

22. Ram, Rati. "Exports and Economic Growth: Some Additional Evidence," *Economic Development and Cultural Change*. Vol. 33, No. 2, 1985, pp. 415-25.

23. Rana, Pradumna B. "Exports, Policy Changes, and Economic Growth in Developing Countries After the 1973 Oil Shock," *Journal of Development Economics*. Vol. 28, 1988, pp 261-64.

24. Riedel, James. "Trade as the Engine of Growth in Developing Countries: A Reappraisal." Staff Working Paper No. 555. The World Bank, 1983.

25. Singer, Hans W., and Patricia Gray. "Trade Policy and Growth of Developing Countries: Some New Data," *World Development*. Vol. 16, No. 3, 1988.

26. Summers, Robert, and Alan Heston. "A New Set of International Comparisons of Real Product and Prices for 130 Countries, 1950-85," *The Review of Income and Wealth*. Series 34, No. 1, Mar. 1988.

27. Tyler, William G. "Growth and Export Expansion in Developing Countries: Some Empirical Evidence," *Journal of Development Economics*. Vol. 9, 1981, pp. 121-30.

28. Vollrath, Thomas L. "A Theoretical Evaluation of Alternative Trade Intensity Measures of Revealed Comparative Advantage," *Weltwirtschaftliches Archiv*, forthcoming.

29. ______. *Competitiveness and Protection in World Agriculture*. AIB-567. U.S. Dept. Agr., Econ. Res. Serv., July 1989.

30. World Bank. *The World Development Report 1987*. New York: The Oxford University Press, 1987.

Estimating Producer Welfare Effects of the Conservation Reserve Program

Patrick Canning

Abstract. *Using a farmland value survey that separated the value of farmland enrolled in the Conservation Reserve Program from all farmland, this article measures gains in producer welfare from program participation. The results distinguish program participant welfare gains from the general income effects that benefit all producers through reduced crop supply. Although program participants received substantial gains, all producers received additional income. Producers have collectively benefited from a rise in the value of U.S. farmland of $11 to $22 per acre due to current and expected future benefits throughout the life of the program.*

Keywords. *Conservation Reserve Program, farmland value, producer welfare, survey data.*

Land conservation practices in the United States are traditionally encouraged through government subsidies. Policies encouraging land conservation "appear to be observationally equivalent to policies intended to support the incomes of farmers as an interest group" (*1*, p. 347).[1] In the case of the Conservation Reserve Program (CRP), farmers' incomes are supported through payments for converting highly erodible farmland to uses that significantly reduce soil erosion. These payments may add to producers' welfare through a reduced income risk (*6*), an excess of payments received over enrollment costs, and a general increase in prices from reduced supplies of commodities that would have been produced on the program-enrolled land. Although one, or a combination of all, of these factors constitutes an argument for a positive welfare effect to farmers from the government payments, the argument does not prove that farmers received any benefits. A more convincing case for welfare gains is made with empirical evidence. The direct and indirect producer welfare effects of the Conservation Reserve Program are measured here with U.S. Department of Agriculture survey data and then compared with recent studies, which estimate program effects through use of secondary, or market level, data.

Background

The Conservation Reserve Program addresses multiple policy concerns. The program's primary goal is to prevent further erosion of fragile farmland. Other goals include reducing surplus crop production and maintaining a strong farm economy (*5*). The CRP targets highly erodible U.S. farmland for enrollment in the program. The landowner receives an annual payment from the government in return for participation. A landowner who participates must not grow crops on the enrolled land for a period of 10 years, but instead must plant a cover of grass or trees.

Farmland owners benefit from the acreage reductions and program rental payments. Each owner of program-eligible farmland submits a bid in the form of a per acre rental rate. For the owner, this bid at least equals the opportunity costs of program enrollment. No profit-maximizing farmland owner will submit a bid below perceived opportunity costs. Thus, the government accepts bids equal to or greater than opportunity costs. Any difference between accepted bids and opportunity costs of enrollment constitutes a direct net benefit to farmers for program enrollment.

Nonparticipants benefit from the program also. Once farmland is enrolled in the program, it is out of crop production, which reduces crop supply. To the extent that program enrollment affects supply, market prices of the subsequent crop supply should increase, which benefits all producers in the affected markets.

Measuring Welfare Effects of the CRP

Three facts must be recognized to identify the CRP benefits to producers. Enrollment in the CRP is an alternative market in which a farmer can participate. A fixed amount of the farm is classified as highly erodible, and therefore eligible for enrollment in the CRP. The CRP is not a commodity-specific program, so assessing welfare effects on producers requires a multimarket framework.

All farm operators have the option of producing many commodities, so we can assume the farm sector will operate such that the sum of profits from all products is maximized. With the CRP, the sector produces n agricultural products plus an income-generating unit, q_{n+1}, which represents total acres of CRP-enrolled land selling at an annual price p_{n+1} per acre.

Economic rent for the profit-maximizing firm producing output i is defined as total revenue less total variable costs. The sum of rents from each of the n+1 markets defines total rent for a multiproduct farm sector.[2]

Canning is an agricultural economist with the Resources and Technology Division, ERS. The author appreciates the comments from Alex Barbarika, Fred Kuchler, Hyunok Lee, Robbin Shoemaker, and two anonymous reviewers of this article, and those from Richard Just on an earlier draft.

[1]Italicized numbers in parentheses cite sources listed in the References section at the end of this article.

[2]The derivations in equations 1 through 4 parallel those for the general case of a multiproduct profit-maximizing firm, as developed in appendix A in (*4*).

$$R = \sum_{i=1}^{n+1} p_i q_i - \sum_{j=1}^{m} w_j x_j, \tag{1}$$

where:
- p_i = unit price for output i,
- q_i = total units of output i,
- w_j = unit price for input j,
- x_j = total units of input j,
- R = total economic rent.

From first-order conditions of profit maximization, q_i and x_j are solved for optimal levels, conditioned on input and output prices. The rent function is then solved for optimal levels, conditioned on input and output prices. Through first-order conditions of the profit function and the envelope theorem, the market supply and factor demand functions are obtained as follows:

$$\frac{\partial R(P, W)}{\partial p_i} = \tilde{q}_i(P, W) = \text{product supply for output } q_i \tag{2}$$

and

$$\frac{\partial R(P, W)}{\partial w_j} = - \tilde{x}_j(P, W) = \text{derived demand for input } x_j, \tag{3}$$

where:
- $P = (p_1, p_2, \ldots, p_{n+1})$,
- $W = (w_1, w_2, \ldots, w_m)$.

For each product i, there exists a market shutdown price $\hat{p}_i$, such that $\hat{p}_i$ is just low enough to induce the farm sector to cease production of good i. Denoting "*" as a flag that indicates a market equilibrium price with the CRP in effect, integration of equation 2, evaluating from $\hat{p}_i$ to p_i^*, will provide the rent generated in market i. Integration from shutdown price to equilibrium price for all products sums to total rent R.

Equation 4 (below) is the summation of total area above the supply curve and below price for all of the n+1 products in the sector. The proof is as follows:

$$\sum_{i=1}^{n+1} \int_{\hat{p}_i}^{p_i^*} \tilde{q}_i\,(P, W^*)\; dp_i$$

$$= \sum_{i=1}^{n+1} \int_{\hat{p}_i}^{p_i^*} \frac{\partial R_i(P, W^*)}{\partial p_i} \; dp_i$$

$$= \sum_{i=1}^{n+1} [R_i\,(P\,(p_i^*), W^*)$$

$$- R_i\,(P\,(\hat{p}_i), W^*)] = R\,(P^*, W^*), \tag{4}$$

where:
$P = (p_1^*, p_2^*, \ldots, p_i, \ldots, p_{n+1}^*)$, and recall $R_i\,(\hat{p}_i) = 0$.

Welfare Effects in Market n+1

The direct welfare effects for CRP participants is defined by the difference between contract payments (p_{n+1}^*) and the opportunity costs of not farming the program land ($\hat{p}_{n+1}$). Prior to the program's inception, $p_{n+1} = \hat{p}_{n+1}$ and $R_{n+1} = 0$. From this initial equilibrium position, the U.S. Department of Agriculture (USDA) began accepting bids submitted by farmland owners. Bids must have been at least equal to the rate $\hat{p}_{n+1}$. There has been an upper limit on acceptable bids. Government-established bid caps represent the maximum acceptable rental rate paid to farmland owners for participation in the program. The value $\hat{p}_{n+1}$ is defined as the rental rate at which the landowner is indifferent between program enrollment and farming the land in its maximum alternative income-generating usage. Any discrepancies between $\hat{p}_{n+1}$ and accepted bids is due to an asymmetry of information between the landowner (who has a good idea of the land's earning potential) and government (which has inferior knowledge of the same value). The initial welfare effect of the program is propagated by creation of a market for q_{n+1}. Measuring this effect is market n+1 amounts to measuring the difference between accepted CRP contract bids and opportunity costs of enrollment. Since bids are in dollars per acre, the difference can be multiplied by total enrolled acres and then summed across the duration of the program. This value, which represents the total welfare effect in market n+1 over the life of the program, is depicted in equation 5 (suppressing the n+1 subscript):

$$W = \sum_{i=1}^{7} \int_{t=0}^{9} \int_{\hat{p}_{t,i}}^{p_{t,i}^*} q_{t,i} e^{-\delta t} dp, \tag{5}$$

where:
- δ = discount rate,
- t = life span of program, that is, 0 is initial year, 9 final year
- i = signup period, that is, there are seven total signup periods,
- W = welfare effect in market n+1 through termination of program.

Equation 5 is difficult to estimate empirically. Although CRP bids p_{n+1}^* are observable, economists usually do not know what individuals believe the alternative, but lower, expected earnings, $\hat{p}_{n+1}$, are. If contract bids are equal to opportunity costs, then equation 5 equals 0. A strategy to determine $\hat{p}_{n+1}$ must be defined if $\hat{p}_{n+1}$ and p_{n+1}^* differ. (At the time of this article's completion, a total of seven signup periods had been conducted.)

Although there are problems estimating each program participant's actual values of p_{n+1}^* and $\hat{p}_{n+1}$, as well as their perceived capitalization rate (δ), each of these components is collectively revealed in the value of farmland. Because farmland values are observable, and farmland value data exist for all geographic regions, equation 5 can be evaluated. Farmland values will also reflect program benefits beyond the termination of program payments. These benefits, which are not represented in equation 5, are realized when employment of the land is resumed by the owner upon

termination of the program. Such factors as improved soil quality and enhanced esthetic qualities, which are a direct result of program enrollment, are anticipated by program participants and capitalized into the present value of the land.

Pricing Farmland

Asset value can be assessed by estimating the income an asset could produce. The nonstochastic formula for pricing farmland postulates farmland value is, at equilibrium, equal to the present value of an income stream generated in perpetuity. This income is generated through employing the land in its optimal profit-generating usage:

$$V = \int_0^{\infty} Re^{-\delta t}dt = \frac{R}{\delta}. \tag{6}$$

V represents the price of the parcel per acre, and R represents the per acre rental rate, discounted at a constant rate compounded continuously (see *8*, p. 57). The improper integral in equation 6 converges, and the value R is defined as in equation 1. In the context of the multiproduct market of equation 5, R is also equivalent to p_{n+1}, which is the rental price per acre of farmland enrolled in the CRP. If bids accepted by the government were equal to the opportunity cost of enrollment $\hat{p}_{n+1}$, then the value of land enrolled in the program would be equivalent to similar land not enrolled. To the extent that the accepted bid (p^*_{n+1}) was greater than $\hat{p}_{n+1}$, the value of CRP-enrolled land is proportionally greater than similar land not enrolled in the program. This difference can be calculated by expanding the expression in equation 6. The difference in the earning potential of farmland enrolled in the CRP and eligible land not enrolled is the government payments p^*_{n+1}, which are earned over a 10-year period:[3]

$$V^{crp} = \int_0^{9} P^*_{n+1}e^{-\delta t}dt + \int_{10}^{\infty} \hat{p}_{n+1}e^{-\delta t}dt. \tag{7a}$$

$$V = \int_0^{9} \hat{P}^*_{n+1}e^{-\delta t}dt + \int_{10}^{\infty} \hat{p}_{n+1}e^{-\delta t}dt. \tag{7b}$$

Subtracting 7b from 7a and multiplying by enrolled acreage shows:

$$q_{n+1} \times (V^{crp} - V) = \left[\int_0^{9} (p^*_{n+1} - \hat{p}_{n+1})e^{-\delta t}q_{n+1}dt\right] + C$$

$$= \left[\sum_{t=0}^{9} \int_{\hat{p}_{n+1}}^{p^*_{n+1}} q_{n+1}e^{-\delta t}dp_{n+1}\right] + C. \tag{8}$$

[3]If the land in 7a and 7b truly are similar, then termination of the program should lead to resuming similar land use patterns. However, there may be environmental benefits that are capitalized in equation 7a beginning in period 10 which do not affect equation 7b.

Calculating equation 8 for contracts across all seven signup periods captures the welfare effects in equation 5. There may also be a residual difference between the last expression in equations 7a and 7b not depicted in equation 5. For example, producers benefit from reduced soil erosion, which can lead to benefits by enhancing the soil's ability to produce in the future (see *12*, p. 15). Since this benefit is not perpetual, it is depicted in equation 8 as a lump sum benefit equal to a constant, C. The total welfare effect in market n+1 can be directly measured as the difference between the weighted average value of farmland enrolled in the CRP and program-eligible land not enrolled across all seven signup periods.

The Data

USDA's Farmland Market Survey polls brokers, appraisers, bankers, and both public and private officials who deal with the agricultural real estate market (*10*). The 1988 survey data included information specifically concerning value of farmland enrolled in the CRP and land eligible for enrollment but not enrolled. Although coverage includes all 10 farm production regions of the continental United States, the Pacific and Northeast regions have limited coverage, so are not considered separately for this study (responses from these two regions, however, are incorporated into the 48-State estimate). Estimates of the percentage effect of program enrollment on CRP-enrolled farmland values (the ratio of CRP-enrolled farmland value to the value of program-eligible land not enrolled) is developed for 10 farm production regions. The 1988 survey was conducted in February 1988, so coincides with the beginning of signup period 6. The survey responses will most likely reflect program effects through five signup periods.

Results and Implications

The national average value of CRP-enrolled farmland is 7 percent greater than program-eligible land not enrolled. Each of the estimated regions also shows significantly greater values for enrolled farmland, ranging from 3 percent in the Lake States region to 12 percent in the Mountain region (table 1). To convert these percentage figures into dollars, assumptions about the characteristics of the farmland sample are necessary. In particular, farmland productivity for erodible farmland is assumed to be similar to nonerodible farmland. This assumption is substantiated by a considerable literature that focuses on land productivity issues.[4] The observed contract rents for the CRP are generally above or rapidly approaching published cash rental rates for cropland (*11*) as shown in table 2. Comparable rental rates between regional farmland enrolled in the CRP and all farmland within each

[4]See (*2*) for analysis and further references.

Table 1—Comparison of survey results to capitalization of initial and subsequent contract bids

Region	Change in value of CRP-enrolled farmland[1]		Equation 9 results through five signups at discount rate of:		Equation 9 results through seven signups at discount rate of:	
			8%	4%	8%	4%
	Percent	*Dollars per acre*				
Northeast	NA	NA	48	57	57	67
Appalachia	5	52	36	42	36	43
Southeast	8	90	67	79	73	86
Delta States	7	55	63	74	66	78
Corn Belt	8	80	74	87	81	95
Lake States	3	24	57	68	57	68
Northern Plains	11	40	18	22	14	19
Southern Plains	7	37	38	44	38	45
Mountain	12	31	36	42	36	43
Pacific	NA	NA	31	36	32	38
48 States	7	44	41	48	42	38

NA = not available.
[1]Column 2 is calculated as the product of column 1 and regional land values based on the 1987 Census of Agriculture (*9*).

Table 2—Average regional contract payments by signup period, and average cash rental rates for cropland

Region	Average payment by signup period							Cash rent, February 1990
	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	
	Dollars per acre							
Northeast	49	56	58	57	57	58	63	46
Appalachia	48	52	54	55	53	53	55	48
Southeast	31	39	42	43	44	44	45	49
Delta States	33	40	44	44	45	45	45	49
Corn Belt	58	63	70	71	69	70	81	83
Lake States	49	52	57	60	59	57	59	54
Northern Plains	44	45	47	48	46	45	44	38
Southern Plains	34	38	40	40	41	40	41	26
Mountain	34	38	40	40	41	40	40	45
Pacific	44	48	49	49	51	51	51	105
48 States	42	44	47	51	48	48	50	NA

NA = not available.

region suggest comparable farmland values,[5] thus providing a basis for converting the regional percentage estimates to dollar figures (table 1).

A variation of the CRP welfare evaluation approach used by Shoemaker (*7*) was employed to test the hypothesis that the average gains per acre of CRP-enrolled farmland did not significantly change after signup period 5. Shoemaker estimated direct welfare gains from participation in the CRP by assuming that signup period 1 bids represented approximate opportunity costs of the average farmland parcel enrolled in the program. Observing subsequent signup period bids asymptotically approaching previously established government bid caps (table 2), Shoemaker assumed that these increased bids reflected farmers' learning established bid caps. The total income effect was calculated by capitalizing the difference between final and initial bids. Shoemaker used final signup period and initial signup period average regional contract payments (table 2) as proxies for p_i^* and $\hat{p}_i$. More precise estimates are possible by weighting the average effect across each signup period.

$$\sum_{i=1}^{5} \left(\frac{a_i}{A}\right) \int_0^9 (p_i^* - \hat{p})e^{-\delta t}dt, \tag{9}$$

where:
a_i = total acreage enrolled in period i, and
A = total acreage enrolled through five signups.

This procedure produces a better representation of the average gain to participants throughout the life of the program. Equation 9 results are presented in table 1. The range represents a discount rate range of 4-8 percent, which is what Shoemaker used.

[5]This is true only under the assumption that farmland's current earning potential can be maintained, in real value, through perpetuity. Because investors in erodible farmland may incorporate an expected long-term loss in productivity, this assumption may overstate the value of CRP-eligible farmland.

For the 48-State estimate, this range is $41-$48 per acre, which is consistent with the survey results in column 2. The regional results do not correspond as closely to the survey regional results, yet an ordering of the regions by the magnitude of their estimates shows a close correspondence of the two estimating procedures. Overall average producer gains after seven signup periods correspond to average gains through five signups, not surprising because the average accepted contract bids leveled off after five signups (table 2).

The hypothesis that the survey data effectively represent the present value of average gains to program participants in all seven signup periods cannot be rejected. Although the survey was conducted after signup period 5, the average per acre gain to program participants in the final two signup periods appears to have remained constant. If that is so, the direct program welfare effects can be quantified as the product of the average per-acre effect ($44) and total enrolled acreage (28.1 million) which comes to $1.24 billion. This value represents the total capitalized value to participants from contract payments above the opportunity cost of program participation, plus all environmental benefits that can be capitalized into the value of the enrolled farmland.

Aggregation of Effects in All Markets

Because decreased production will cause upward pressure on prices in affected markets, the land that remains in production will earn higher rents, thus causing further welfare effects to producers participating in these markets. The empirical results of the previous section account for welfare effects beyond the price effects that may have occurred. This is so because farmland owners will have anticipated the supply effects, which would be reflected in the value of farmland not enrolled in the program.

The welfare effects across all n+1 output markets are measured by the area below the derived demand for farmland. Markets 1 through n+1 all clearly require a positive amount of farmland to produce output q_i. There exists some positive price for farmland, $\hat{w}_j$, which will lead to a shutdown of demand for farmland x_j. This price is observed at the farm level by the conversion of farmland at the urban fringe to residential or commercial development. At more aggregated levels, this price will likely not be reached. However, short of a global shutdown, large regions can become entirely dependent on an outside supply of agricultural products. When a shutdown occurs in the market for land, the entire agricultural sector will shut down, reducing rents to zero. Using this notion of a shutdown price, plus equations 3 and 4, the change in welfare across markets 1 through n+1, resulting from a change in price p_{n+1} from $\hat{p}_{n+1}$ to p^*_{n+1} is measured by the change in area below the demand for farmland and between the price for farmland with and without the CRP.

Equation 10c establishes that the difference in area below the derived demand for farmland and between $\hat{w}_j$ and w^*_j is equivalent to the change in welfare for the farm sector due to introduction of the CRP:

Denote C_1 total welfare in sector with the CRP, C_2 total welfare in sector before the CRP, and w_j the price of farmland.

$$C_1 = \int_{w^*_j}^{\hat{w}_j} x_j\,(P(p^*_{n+1}),\ w^k_i,\ w_j)\,dw_j = -\int_{w^*_j}^{\hat{w}_j} \frac{\partial R\,(P(p^*_{n+1}),\ w^k_i,\ w_j)}{\partial w_j}\,dw_j = R\,(P(p^*_{n+1}),\ W^*). \tag{10a}$$

$$C_2 = \int_{w^*_j}^{\hat{w}_j} x_j\,(P(\hat{p}_{n+1}),\ w^k_i,\ w_j)\,dw_j = -\int_{w^*_j}^{\hat{w}_j} \frac{\partial R\,(P(\hat{p}_{n+1}),\ w^k_i,\ w_j)}{\partial w_j}\,dw_j = R\,(P(\hat{p}_{n+1}),\ W^*), \tag{10b}$$

where:

$w^k_i = (w^k_1, \ldots, w^k_{j-1}, w^k_{j+1}, \ldots, w^k_m)$,

$k = 0, 1$, e.g., before or during CRP,

$P(p^*_{n+1}) = (p^*_1, \ldots, p^*_n, p^*_{n+1})$,

$P(\hat{p}_{n+1}) = (p^*_1, \ldots, p^*_n, \hat{p}_{n+1})$.

$$C_1 - C_2 = R(P(p^*_{n+1}), W^*) - R(P(\hat{p}_{n+1}), W^*). \tag{10c}$$

Observed changes in farmland values are general equilibrium changes that reflect conditions throughout the sector as well as any outside sector effects such as the influence of urbanization. To isolate the effect on farmland value attributed solely to the CRP, note that the program payments, environmental benefits to program-enrolled farmland, and a risk premium from contract payments are all (or primarily) in the $1.24-billion welfare gains captured in market n+1. The remainder of the program effects on producer welfare are in the affected commodity markets.

There are three possible price effects in the commodity markets affected by the CRP. If all program-enrolled cropland were used for crops that were at or near unitary price elasticity for output demand, then the welfare effect for markets 1 to n would be 0, since unitary price elasticity implies price changes are revenue neutral. Under unitary elasticity, equation 10c is the observational equivalent to equation 8, and the survey results in table 1 represent the total producer welfare effect of the CRP. If these crops are instead generally elastic, then markets 1 to n will have a negative net welfare effect since price elastic demand for

agricultural products implies price increases are revenue-decreasing. The amount of lost revenue under this scenario should not exceed the gains in market n+1, as this would make the program a net loser for producers. If net losses were even remotely possible, farmers would most likely anticipate losses, and program participation would be very low. For this scenario, total CRP welfare effects would range between 0 and the amount defined in table 1. The scenario most likely to represent the majority of markets affected by the program will be that of an inelastic demand for producer output.[6] A price inelastic demand for agricultural output will result in adjustments in demand that do not offset price increases, thus enhancing producer revenue. For this reason, the survey results in table 1 most likely are a lower bound of the total welfare effects from the CRP. To measure all effects, a general equilibrium solution must be solved simultaneously. That solution may be empirically intractable.

A partial equilibrium approach to measuring the total welfare change, outlined in Just, Hueth, and Schmitz (*4*, p. 211) identifies a subset of markets that are significantly affected by the policy considered. If the number of markets significantly represents the scope of affected markets, yet is not too large to manage, then this subset can be treated as a market, and welfare effects can be measured by simultaneously solving for the new equilibrium. In terms of a regional analysis, this approach has empirical possibilities in the more homogeneous areas of the country. For example, in the Corn Belt States, corn and soybeans dominate the market for cropland throughout the region. Modeling the effects of the CRP could be achieved by considering these two markets plus some set of related markets that could be considered jointly. In contrast to the Corn Belt, the Pacific is a very diverse production region and a large number of markets must be considered to capture a majority of the program effects. Tractability may be a problem in the Pacific region.

A recent study by Young and Osborn (*12*) in effect identifies the U.S. agricultural sector as a tractable subset of markets affected by the CRP. They estimated the net present value of producer income effects from the CRP to range between $9.2 billion and $20.3 billion. These results are from an agricultural sector partial equilibrium model and correspond to total income effects in markets 1 through n. The wide range in their income effect estimates reflects the tractability problem and is based on alternative policy and price effect assumptions.

Total producer welfare gains from the CRP, using the partial equilibrium approach of Young and Osborn and the survey results of table 1, are the sum of these two effects, or between $10.44 billion and $21.54 billion. The present discounted value of all producer welfare effects from the CRP thus increases the average value of U.S. farmland between $11 and $22 per acre.[7] The equality of this sum and total producer welfare gains from the CRP is evidenced by noting that land value represents the capitalized value of expected rent (equation 6), and adjustments in the value of farmland represent the sum of all producer adjustments in total welfare (equation 10c).

Conclusions

The empirical results presented are observed program effects through five signup periods of the Conservation Reserve Program. Indications from the average bids in the final two signups suggest that the empirical results probably represent the average effect across all signup periods. These results represent the average effects of program payments, which include marginal (payments equal opportunity costs) and inframarginal (payments in excess of opportunity costs) farmland enrollment. The regions analyzed unanimously indicate a net positive effect in land value due to program enrollment. A null hypothesis that program payments are not greater than opportunity costs is refuted by the paradoxical implications of such an assertion. If the null hypothesis were true, the empirical results would indicate that the most productive farmland has been taken out of production in favor of highly erodible, unproductive farmland. This would be contrary to program objectives, and would be highly unlikely.

Although comparisons are made with results from recent studies measuring CRP program effects, the survey results, unlike the simulated results, are independent of any underlying model. They are consistent with assumptions of contract prices in excess of expected rents, yet would not contradict a scenario where contract prices are identical to expected rents, such that welfare gains are attributed to a risk premium. The empirical results also capture investor expectations of environmental benefits that can be capitalized into the value of farmland. This is significant because it establishes a lower bound for measuring program benefits in the farm sector. The curtailed supply of crops affected by the program increases the welfare of all producers considerably more than direct welfare effects to program participants.

References

1. Gardner, Bruce L. *The Economics of Agricultural Policies.* New York: Macmillan Publishing Company, 1987.

[6]In an analysis of price elasticity for 40 major food items, Huang (*3*) estimates that grapes are the only crop that is price elastic.

[7]Calculated from the quotient of total estimated welfare effects and the 1987 U.S. Census of Agriculture land in farms figure.

2. Heimlich, R.E. *Productivity and Erodibility of Cropland Resources.* AER-604. U.S. Dept. Agr., Econ. Res. Serv., Jan. 1989.

3. Huang, Kuo S. *U.S. Demand for Food: A Complete System of Price and Income Effects.* TB-1714. U.S. Dept. Agr., Econ. Res. Serv., Dec. 1985.

4. Just, Richard E., Darrell L. Hueth, and Andrew Schmitz. *Applied Welfare Economics and Public Policy.* Englewood Cliffs, NJ.: Prentice-Hall, Inc., 1982.

5. Osborn, C. Tim, Felix Llacuna, and Michael Linsenbigler. *The Conservation Reserve Program: Enrollment Statistics for 1987-88 and Signup Periods 1-7.* SB-785. U.S. Dept. Agr., Econ. Res. Serv., Sept. 1989.

6. Scott, John T. "Midwest Farmland Values and Government Subsidies to Agriculture." Urbana-Champaign: Illinois Agr. Econ. Staff Paper 89E-438, May 1989.

7. Shoemaker, Robbin. "Agricultural Land Values and Rents Under the Conservation Reserve Program," *Land Economics.* Vol. 65, No. 2, May 1989, pp. 131-37.

8. Silberberg, Eugene. *The Structure of Economics.* New York: McGraw-Hill, 1978.

9. U.S. Department of Commerce, Bureau of the Census. *1987 Census of Agriculture.* Vol. 1, Geographic Area Series, Part 1 to Part 50, State and County Data, 1989.

10. U.S. Department of Agriculture. *Major Statistical Series of the U.S. Department of Agriculture, Land Values and Land Use.* AH-671, Vol. 6, Aug. 1988.

11. U.S. Department of Agriculture, Economic Research Service. *Agriculture Land Values and Markets: Situation and Outlook Report.* AR-14, June 1989.

12. Young, C. Edwin, and C. Tim Osborn. *The Conservation Reserve Program: An Economic Assessment.* AER-626. U.S. Dept. Agr., Econ. Res. Serv., Jan. 1990.

Welfare Gains From Wood Preservatives Research

Barry J. Seldon and William F. Hyde

Abstract. *The economic productivity of publicly funded wood preservatives research from 1950 to 1980 exemplifies public research in the forest product industries. We find a high internal rate of return for wood preservatives, nearly 300 percent. The research investments would not have been made by private industrial investors, however, since the welfare gains are not captured by producers. This provides justification for government involvement in research. The marginal internal rate of return is negative, indicating that the internal rate of return would have been even higher with less funding.*

Keywords. *Research and development, research evaluation, technical change, innovation, wood preservatives, forest products.*

Wood preservatives research by USDA's Forest Products Laboratory (FPL) in Madison, WI, is an excellent example of public forestry research. Since it was formed in 1910, the FPL has conducted much of the Nation's research on wood preservatives. The returns to this research have not been studied previously. An evaluation of the welfare effects of FPL wood preservatives research may be a useful platform from which to view forest product research in general.

We examine the social productivity of FPL wood preservatives research in 1950-80 as an example of what may be a general case for public research in the forest product industries. Our approach relies on econometric estimation of coefficients in a supply function derived from a standard production function using results from duality theory (*3*).[1] We then develop a method for estimating the internal rate of return (IRR) for public investments. By estimating the effect of research and development (R&D) on the supply curve directly, we avoid the error of attributing all outward shifts in supply to R&D. The method is similar in spirit to one used by White and Havlicek and follows Seldon's analysis of the softwood plywood (SWPW) industry (*19*, *14*). His estimates of the IRR for public softwood plywood research range upward to a surprising 400 percent, depending on various possible estimates for private development costs associated with public research investments.

This paper follows the earlier SWPW study in specifying a supply and demand system and determining the IRR to public research. It then extends the method to calculate the value of the marginal product (VMP) and the marginal internal rate of return (MIRR). The duality between production and supply makes this extension possible. A glance ahead to the results shows that we find a large IRR, comparable to that for the SWPW industry, but a potentially negative MIRR.

Background

The four-firm concentration ratio for the wood preservatives industry was in the 30-40 percent range throughout the period of our inquiry. Therefore, the industry is competitive and we can define its supply function.

Wood preservatives extend the life of treated wood products. Therefore, one effect of wood preservatives research is on product quality. Improved quality benefits consumers, but it is not the cost-reducing research reflected in most economic measures of technical change. Wood preservatives are generally petroleum products, so the residuals created while treating wood with petroleum products are environmentally objectionable. Therefore, much recent research in the wood preservatives industry has the objective of lowering levels of associated environmentally damaging residuals while still producing the same product. These changes in residuals are also hidden from our output measure for the basic product. Our eventual estimates of research productivity in the wood preservatives industry will be underestimated by the magnitude of product quality and environmental research impacts.

Supply and Demand

Studies focusing on the impact of R&D on productivity often employ a flexible form of the production function that allows analysts to consider the interactions among inputs (see, for example, *2*, *8*). In this study, however, these interactions are not important considerations. Therefore, we follow the advice of Griliches and use the Cobb-Douglas form (*5*). The exact form is the variant developed by Seldon (*14*). The production function at time t is:

$$Q_t = e^{\theta t} L_t^{\alpha_1} K_t^{\alpha_2} Y_t, \tag{1}$$

where Q is the quantity produced, e is the base of natural logarithms, θ is the rate of disembodied technical change associated with t (a proxy for disembodied

Seldon is with the School of Social Sciences, The University of Texas at Dallas, Richardson, TX. Hyde is an economist with the Resources and Technology Division, ERS. USDA's Forest Service Southeastern Forest Experiment Station funded this research. A. Bruner and J. Strauss provided research assistance. The authors thank the reviewers of this article for their helpful comments.

[1] Italicized numbers in parentheses cite sources listed in the References section at the end of this article.

change as in *6*), L is labor services, K is capital services, and:

$$Y_t = \prod_{i=i_0}^{\infty} (Z^{\eta}_{t-i} G^{\mu}_{t-i-j_0})^{\lambda^{i-i_0}};\ i_0 > 0,\ j_0 \geq 0 \quad (2)$$

is the accumulated research effort, G is government R&D, and Z is private R&D performed by the suppliers of the final product. The coefficient λ is inversely related to the depreciation rate. Therefore, new research replaces older research and research obsolescence sets in more rapidly for smaller λ's. Private R&D does not affect productivity for i_0 periods since it takes time for manufacturing plants to adopt the new knowledge. For similar reasons, government research does not affect productivity for i_0+j_0 periods. The lag until the initial impact of public R&D, i_0+j_0, must be at least as long as the lag preceding the initial impact of publicly induced private R&D, i_0, because producers must be made aware of the government R&D.

If firms in the wood preservatives industry are competitive profit maximizers, then the industry as a whole solves the problem:

$$\max_{L_t,\, K_t} \quad \pi_t = P_t Q\,(L_t,\, K_t,\, Y_t) - W_t L_t - R_t K_t - Z_t, \quad (3)$$

where π is profit, P is the price of the good, and W and R are the wage rate and the cost of capital. We substitute the Cobb-Douglas form from equation 1 for the expression Q in equation 3.

We solve equation 3 in terms of L and K and equate the results with zero in order to derive the supply function (*14*). The distributed-lag form of industry supply in logarithm form is:

$$\begin{aligned} q_t = {} & (1-\lambda) \ln A + \gamma(\alpha_i + \alpha_2)(p_t - \lambda p_{t-1}) \\ & - \gamma\alpha_1 (w_t - \lambda w_{t-1}) - \gamma\alpha_2(r_t - \lambda r_{t-1}) \\ & + \gamma[\theta t - \lambda\theta(t-1)] + \gamma\eta z_{t-1} + \gamma\mu g_{t-1} + \lambda q_{t-1}, \quad (4) \end{aligned}$$

where q, p, w, r, z, and g denote the logarithms of Q, P, W, R, Z, and G, and A and γ are constant functions of α_1 and α_2. The definitions for the exogenous variables and data sources are:

q = a volume measure of preserved wood products (U.S. Department of Commerce *Census of Manufactures*, various years),

p = own price (value of shipments divided by quantity, deflated by the 1967 producer price index) (U.S. Department of Commerce *Census of Manufactures*, various years),

w = average hourly wage for production workers in wood preservatives (U.S. Department of Commerce *Census of Manufactures*, various years.),

r = real user cost of capital for wood products (Wharton Econometrics, personal correspondence),

z = a proxy for private R&D expenditures: total revenue or price times quantity, since R&D is a fixed share of receipts (Mansfield, 1968, National Science Foundation, various issues), and

g = government scientist months (various FPL attainment reports).

Public and private research lags of only 1 year give the best fit. The selection of these lags depends on a three-step process: (1) choice of the best linear two-stage least-squares (2SLS) fit for the lag in a linear version of the basic industry supply function (equation 4), (2) application of this chosen lag in the general supply equation, then (3) retests of the fully specified equation 4 with various similar lags. These 1-year lags are short, and perhaps are due to the fact that improved wood preservative technologies seldom require new equipment, or perhaps because the FPL association with the American Wood Preservers Association is so close that information dissemination is easy and rapid.[2] In any case, FPL personnel anticipate short lags in this industry, and our statistical tests support them. (These lags compare with the combined 2-year public and private lag in the SWPW industry (*14*).)

Generating the demand function is more difficult than the supply function. Creating a single general production function for the collection of heterogeneous consumers of preserved wood products (railroads, telephone companies, homebuilders, farmers, users of marine pilings) is difficult. Therefore, the preferred approach of deriving downstream consumers' demand from their profit functions could not be used. We experimented with several alternate demand forms. Specifications with a trend for the business cycle seem to work well. The intuitive justification is that consumers are so heterogeneous that, taken together, their expansions and contractions would reflect the general economy rather than any single element of it. The generalized demand function (with anticipated signs of coefficients in parentheses) is:

$$q_t = \beta_0 + \underset{(-)}{\beta_1 p_t} + \underset{(+)}{\beta_2 b_t} + \underset{(?)}{\beta_3 \tau} + \underset{(?)}{\beta_4 \tau^2}, \quad (5)$$

where b is the log of net sales in manufacturing industries (*18*), and τ is the time variable proxy for exogenous changes in the level of use of treated lumber in downstream industries.

Net sales performs better than other proxies for the business cycle. The two time variables permit exponential adjustment in the industry but their antici-

[2]For examples, FPL researchers regularly serve on the American Wood Preservers Association staff, and 20 percent of all AWPA publications since 1905 have been written by FPL researchers.

pated signs are uncertain. Exponential decline is plausible for railroad consumption of crossties, and exponential expansion is even more likely for the use of many inorganic preservatives and for recent residential construction uses of treated lumber.

Table 1 shows the nonlinear two-stage least squares (NL2SLS) estimates for both the supply and the demand equations 4 and 5. All coefficients in the supply equation, except the coefficient for disembodied technical change, θ, have the anticipated sign. The coefficients on labor (α_1), capital (α_2), and public research (μ) are not statistically significant at the 10-percent level.[3] There are three significant coefficients, those associated with private R&D (η), R&D depreciation (λ), and disembodied technical change (θ). The independent variables explain 93 percent of all variance in the quantity supplied. Durbin's *h* statistic indicates that serial correlation is not a problem.

The insignificant coefficient on public research is disappointing but not surprising. The public research variable includes research efforts to reduce production cost, enhance product quality, and reduce negative externalities. We know that the latter two have little or no relationship to our measure of quantity. If they dominate and they are not serially collinear with cost-reducing research effort, then they are unrelated to the level of cost-reducing technical change, and we must anticipate an insignificant coefficient on public research effort. Of course, this masks statistical confidence in our estimates of cost-reducing public research.[4]

The negative sign on θ, reflecting negative disembodied technical change, is unusual, probably indicating that industrywide technical change has been unable to keep pace with either industrywide product standards or (more likely) increasing restrictions on petroleum product residuals. That is, research causing decreasing final levels of residuals may not have progressed rapidly enough to maintain industry production at the old levels existing before the new environmental restrictions. In any case, while this negative coefficient reflects unexplained relative industry decline, it has no impact on our measurement of the benefits of cost-reducing research.

All demand coefficients are statistically significant at the 5-percent level or better. The positive coefficient on business activity, β_2, suggests that demand is procyclical, as expected. Demand is also price elastic, as expected, because there are many substitutes for treated wood products (untreated wood, metal, and concrete posts, for example). Differentiating the antilog of the log-linear demand function with respect to τ shows that demand decreased through the 14th period (1964) and increased thereafter. The lower R^2 is not surprising for this *ad hoc* specification of what should properly be a derived demand for a heterogeneous collection of consumers.

Table 1—NL2SLS estimates of demand and supply coefficients for wood preserving[1]

Supply		Demand	
Labor	0.037	(β_0)	11.611*
(α_1)	(.085)		(4.251)
Capital	.009	Own price	–1.621*
(α_2)	(.010)	(β_1)	(–.650)
		Business	
Z_{t-1}	.440**	activity	.929*
(η)	(.216)	(β_2)	(.255)
G_{t-1}	.019	time	–.056**
(μ)	(.060)	(β_3)	(–.023)
lag	.322***	time²	.002*
(λ)	(.218)	(β_4)	(.0004)
Time	–.014**		
(θ)	(–.007)		
R^2	0.93		0.64
Durbin's *h*	–.05		
Durbin-Watson			2.03
Degrees of freedom	25		24

[1]Durbin's *h* tests for autocorrelation in the supply equation because it has a lagged endogenous term, while the Durbin-Watson statistic tests for autocorrelation in the demand equation.
Numbers in parentheses are standard errors.
* = Significant at the 1-percent level in a one-tailed test.
** = Significant at the 5-percent level in a one-tailed test.
*** = Significant at the 10-percent level in a one-tailed test.

A low R^2, such as that found for the demand equation, may suggest that an important variable is missing from an equation. This led us to examine the error terms, because a missing variable will normally induce a pattern into the error term over time similar to the effect of autocorrelation. However, no such patterns existed in the error term, producing no evidence of a missing variable. Regardless of the potential estimation problem, any absent variable causes no problems for our analysis of research benefits so long as the potentially absent term is not collinear with the price coefficient. The price coefficient (more precisely, the price elasticity that derives from it) is the only demand information used in our eventual estimation of research benefits.[5]

Calculating Returns

Following is a review of the general calculations underlying our eventual estimates of the net present

[3]Numerous analyses of R&D investments do not obtain statistical significance. In such cases, analysis in the agricultural research literature proceeds as long as the signs can be interpreted as satisfying economic reasoning.

[4]Since the coefficient associated with government R&D is insignificant, one might conclude that the true coefficient is zero. If so, then the gross benefits would be zero and the net returns would be negative since research would have no effect upon supply and price. But, in fact, producers have adopted the methods and it seems implausible to support that this adoption has no effect on supply. We believe our estimates are as accurate as can be obtained, given current methods.

[5]There are no econometric analyses of the wood preservatives industry known to us. Therefore, there are no comparable elasticity estimates to use to check our results.

value, IRR, VMP, and MIRR associated with public research expenditures. All elements build on our knowledge of the estimated supply and demand functions and the research-induced shifts in supply over time.

The supply and demand system in period $t + 1 + j$ ($j > 0$) due to a given level of R&D expenditure G (the antilog of g) in period t is:

$$S_t G_t^{a_2 \lambda^j} P_{t+1+j}^{a_1} = D_t P_{t+1+j}^{-a_3}. \tag{6}$$

All variables, including G for periods prior to t, remain at their previous levels. $Ln(S_t)$ and $ln(D_t)$ include the intercepts of the log linear supply and demand system at time t, $a_1 = (\alpha_1 + \alpha_2)/(1 - \alpha_1 - \alpha_2)$ is the supply elasticity, $a_2 = \gamma\mu$, and $-a_3 = \beta_1 < 0$ is the demand elasticity. Equation 6 determines the equilibrium future price P^E in the $(t + 1 + j)$th period as $P^E_{t+1+j} = P_t G_t^{-\sigma a_2 \lambda^j}$, where $\sigma = 3(a_3 + a_1)^{-1}$.

The expressions for the present values of consumers' and producers' surpluses, PV^{cs} and PV^{ps}, due to R&D in period t are:

$$PV_t^{cs} = (1-a_3)^{-1} P_t Q_t \sum_{i=1}^{\infty} (1+\rho)^{-i} (1 - G_t^{\sigma\lambda^{i-1}}), \tag{7}$$

and

$$PV_t^{ps} = (1+a_1)^{-1} P_t Q_t \sum_{i=1}^{\infty} (1+\rho)^{-i} (G_t^{\omega\lambda^{i-1}} - 1), \tag{8}$$

where ρ is the discount rate, $\sigma = -a_2(1 - a_3)$, and $\omega = -\sigma$. The terms must be approximated by limiting the summations to the finite number of periods before the R&D contribution of the tth period depreciates sufficiently that the supply is again close to the original period supply. We limit the summation to 15 periods. Subtracting total (public plus induced private) R&D expenditures, E_t, from PV_t^{cs} and PV_t^{ps} yields the net present value of R&D in each period. Summing the discounted terms for each year in the period 1950-80 yields the net present value (NPV) of the entire research program. For example, for consumers' surplus:

$$NPV^{cs} = \sum_{t=0}^{30} (1+\rho)^{-t} (PV_t^{cs} - E_t). \tag{9}$$

The IRR for equation 9 is the value of ρ which equates net present value with zero.

We will soon derive the value of the marginal product for public R&D expenditures (VMP). In the VMP derivation, we will need an expression for the term $\partial Q/\partial E$, so we develop the expression first to preserve the continuity of the derivation of the VMP. Note that since output Q is a function of public research effort G (measured as scientist months), and since public research effort G is a function of public expenditures E, we may use the chain rule to find that $\partial Q/\partial E = (\partial Q/\partial G)(\partial G/\partial E)$. G (government scientist months) increases as E increases, so $\partial G/\partial E$ is strictly increasing (hence monotonic) in E. Therefore, the inverse of $\partial G/\partial E$, which is $\partial E/\partial G$, exists. In fact, since $E_t = C_t G_t$ (where C_t is the average cost of a scientist month in year t), it is easy to see that $\partial G/\partial E = 1/C_t$. Then, using $\partial Q/\partial E$ from above and the fact that $\partial G/\partial E = 1/C_t$, it follows that:

$$\partial Q/\partial E = (1/C_t)(\partial Q/\partial G). \tag{10}$$

We next derive the VMP of R&D. The VMP of any input is simply the price of the output times the marginal product of the input. While the VMP of R&D expenditures may be treated much the same as the VMP of any other input for any single period, the effects of R&D can last many periods into the future. Therefore, the annual effects must be discounted and summed. The discounted VMP of public research conducted in time t in terms of the additional output in period $t+1$ is:

$$\begin{aligned} VMP_t^{s,t+1} &= P_{t+1} (\partial Q_{t+1}/\partial E_t)/(1+\rho) \\ &= P_{t+1} (\partial Q_{t+1}/\partial G_t)/[(1+\rho)C_t], \end{aligned}$$

(while $VMP_t^{s,t} = 0$ since the lag between research expenditures and its initial impact on output is 1 year; research in time t has no effect on output in time t). In our Cobb-Douglas case, we can substitute for $\partial Q_{t+1}/\partial G_t$ in the previous equation to obtain the following:

$$\begin{aligned} VMP_t^{s,t+1} &= \mu P_{t+1} Q_{t+1}/[(1+\rho)G_t C_t] \\ &= \mu P_{t+1} Q_{t+1}/[(1+\rho)E_t]. \end{aligned}$$

Similarly, for any period $t+1+m$, $m > 0$, we obtain the returns to research conducted in time t:

$$VMP_t^{s,t+1+m} = \lambda^m \mu P_{t+1+m} Q_{t+1+m}/[(1+\rho)^{(1+m)} E_t],$$

where the λ^m accounts for R&D depreciation. The full VMP at time t is the sum of these single-period returns:

$$VMP_t = \sum_{m=0}^{\infty} \lambda^m \mu P_{t+1+m} Q_{t+1+m}/[(1+\rho)^{(1+m)} E_t]. \tag{11}$$

Thus, we could estimate the VMP for each investment period in the sample. It is more common, however, to report the geometric mean of the entire series of VMP's (see *5*, *11*).

The MIRR is the value of ρ that equates the geometric means of equation 11 with unity. This conforms with the more general forms of the MIRR (*4*, *19*) since the weight associated with the current period is zero.

R&D Cost Estimates

We need estimates of the direct costs of FPL research and also the public research-induced costs of private implementation. The FPL can provide a history of its research effort. Identifying the costs of private implementation is more difficult. We develop two alternative estimates to suggest a range in which true implementation costs, and true returns to research, may fall.

Suppose that each dollar of FPL expenditure necessitates an expenditure of n private dollars per plant. Total expenditure E_t can be expressed as $E_t = (1 + nN_t)c_tG_t$, where N_t is the number of mills and c_t is the direct cost of a scientist month. Thus, the C_t of equation 10 equals $(1 + nN_t)c_t$.

We constructed c_t from Sonka and Padberg's (*15*) academic price index and Callaham's (*1*) estimated cost of a USDA Forest Service scientist year for 1977, and then we added overhead estimates supplied by the FPL (table 2). N_t is from various issues of the *Census of Manufactures Industry Series*, with linear interpolations for missing years. (The number of plants ranged from 262 in 1950 to 498 in 1980.)

The value of n, the induced private effort is the most uncertain part of the analysis. We obtain a measure of n from knowledge of a single representative case, and then test our research benefit estimates for sensitivity to variation in this measure.

Our representative case is the visual screening techniques for examining wood prior to treatment.[6] Industry implementation of these techniques began in 1968. Visual screening requires an additional employee per plant, which, with appropriate discounting, converts to a private expenditure of 12 cents (1967 dollars) per manufacturing plant for every public research dollar. We will compare gross public wood preservatives research benefits with the sum of public research costs plus this additional induced private cost and with a 50-percent increase in this cost to 18 cents per manufacturing plant. Greater induced private development costs imply lower net economic benefits and lower rates of return to public research.

Table 2—FPL effort in wood-preserving research, 1950-80

Year	Scientist months	Cost per scientist month[1]	Total cost
	Number	*—Thousand dollars[2]—*	
1950	36	5.20	187
1951	50	4.86	243
1952	47	5.12	240
1953	44	5.25	231
1954	43	5.31	228
1955	42	5.42	228
1956	61	5.39	329
1957	77	5.36	413
1958	78	5.37	419
1959	78	5.49	428
1960	73	5.61	410
1961	96	5.74	551
1962	123	5.85	720
1963	131	6.02	788
1964	138	6.16	850
1965	136	6.22	846
1966	122	6.25	762
1967	120	6.49	779
1968	122	6.61	806
1969	128	6.72	860
1970	94	6.86	645
1971	128	6.97	893
1972	141	7.03	991
1973	130	6.74	876
1974	97	6.73	604
1975	82	6.40	524
1976	119	6.27	746
1977	148	6.23	922
1978	126	6.27	790
1979	141	5.96	841
1980	89	5.46	486

[1]Includes overhead.
[2]1967 dollars.
Source: FPL attainment reports.

Results: The Efficiency of Public Wood Preservatives Research

Table 3 displays most of our summary results for the two cases where publicly induced private development costs are 12 cents and 18 cents per manufacturing plant and for the range of social discount rates between 4 percent and 10 percent. The next returns to producers are negative for both R&D cost alterna-

[6]Researchers at the FPL confirmed the selection of these techniques as representative in its requirement for industrial modification and development in each plant. (L. Gjovick, personal communication, Nov. 1988.)

Table 3—Returns to public investment in wood-preserving research, 1950-80

Multiplier		Social discount rate 0.04	0.07	0.10
		—Million dollars[1]—		
0.12	NPV^{cs}	86.1	61.9	49.1
	NPV^{ps}	–118.1	–68.3	–40.2
	NPV^{neb}	384.1	251.9	179.4
	BC^{cs}	1.16/1	1.16/1	1.17/1
	BC^{neb}	1.85/1	1.85/1	1.87/1
	IRR^{cs} not reported: multiple solutions exist			
	IRR^{neb} = 293 percent			
0.18	NPV^{cs}	–117.3	–64.2	–34.1
	NPV^{ps}	–321.6	–194.4	–123.4
	NPV^{neb}	180.7	125.7	96.2
	BC^{cs}	.78/1	.78/1	.79/1
	BC^{neb}	1.24/1	1.24/1	1.25/1
	IRR^{cs} not reported: multiple solutions exist			
	IRR^{neb} not reported: multiple solutions exist			

[1]1967 dollars.

tives and for the full range of social discount rates. Net producers' surplus is generally positive for only six or seven individual years in the 1950-80 period. This means that producers would not have conducted this research themselves. Net consumer gains are positive for the 12-cent private development cost case but negative for the 18-cent case, regardless of social discount rates in our range. The combined net benefits to producers and consumers are positive in all cases. (Recall that our calculations of net benefits to consumers (NPV^{cs}) and net benefits to producers (NPV^{ps}) are both net of research expenditures. Therefore, the net benefit to society (NPV^{neb}) is greater than the sum $NPV^{cs} + NPV^{ps}$ by the amount of total R&D expenditures because the sum subtracts total R&D expenditures twice. Rows 1-3 and 8-10 in table 3 reflect this result.) The positive social gain, yet negative producer gain, justifies the public FPL research presence.

Table 4 shows the annual sequence of net consumer and producer surpluses and net social gain for the single case of 12-cent private development costs and a social discount rate of 4 percent. This table shows the periodic switching from positive to negative values that prevents us from obtaining solutions for the various internal rates of return in table 3. Table 4 shows why the benefit-cost ratio increases with greater social discount rates. For example, net losses occur in later years for consumers and are, therefore, discounted more heavily than the larger net gains of the earlier years.

Table 5 reports the periodic annual values of marginal products (VMP's), the average VMP, and the marginal internal rate of return (MIRR). Annual and average VMP's less than one and MIRR's less than zero indicate an overinvestment in public wood preservative research. This observation is all the more true for more recent years during the 30-year period. These were also years of rising petroleum product prices and the years of largest research investments in controlling environmental residuals. Removing the costs of these latter environmental and product-quality research efforts may raise the MIRR to the positive range and remove the question of overinvestment.

If we consider all public research investments to be of the cost-saving variety, then investments in wood preservative research would have been socially wise ($NPV^{neb}>0$) but would not have been made by private industrial investors ($NPV^{ps}<0$). It would have been even wiser, however, for the FPL to invest but at a lower total level each year (VMP<1), MIRR<0). The net social gains (NPV^{neb}) would have been greater than those we observed.

When we acknowledge substantial product quality improvement and environmental investments in wood preservative research, then we know that our summary benefit measures are all lower estimates. Returns to public wood preservative research were at least as great as those we reported for cost-reducing research, and our subjective judgment is that the net public gains may have been positive in all scenarios.

Table 4—Returns to wood preservatives research, by individual year (multiplier = 0.12, discount rate = 0.04)

	Net present value of returns to:		
Year	Consumers	Producers	Consumers and producers
	Million dollars[1]		
1950	12.0	4.6	22.7
1951	13.4	4.7	26.1
1952	13.8	4.9	26.9
1953	12.2	4.0	24.2
1954	11.0	3.3	22.4
1955	10.7	3.0	22.0
1956	11.3	1.8	25.2
1957	10.3	–.1	25.6
1958	3.9	–4.1	15.6
1959	4.6	–4.0	17.1
1960	5.3	–3.4	18.1
1961	.4	–8.8	13.7
1962	–4.8	–14.8	9.9
1963	–5.8	–16.8	10.2
1964	–6.6	–18.7	11.1
1965	–7.1	–19.3	10.8
1966	–1.1	–14.6	18.6
1967	–1.0	–15.2	19.6
1968	–.5	–15.6	21.6
1969	–6.4	–20.3	14.0
1970	2.8	–10.9	22.8
1971	–5.7	–21.0	16.5
1972	–6.7	–23.7	18.1
1973	–1.5	–18.8	23.7
1974	14.6	–4.1	41.8
1975	6.5	–7.5	26.9
1976	–1.9	–17.7	21.1
1977	.7	–20.5	31.8
1978	11.4	–11.8	45.2
1979	5.5	–17.0	38.3
1980	19.7	–.3	48.9

[1]1967 dollars.

References

1. Callaham, R.Z. *Criteria for Deciding About Forestry Research Programs.* U.S. Dept. Agr., Forest Service, Gen. Tech. Rep. WO-29, 1981.

2. Caves, D., L. Christensen, and J. Swanson. "Productivity Growth, Scale Economies and Capacity Utilization in U.S. Railroads, 1955-1974," *American Economic Review.* Vol. 70, No. 3, 1981, pp. 994-1,002.

3. Chambers, R.G. *Applied Production Analysis: A Dual Approach.* Cambridge, England: Cambridge University Press, 1988.

Table 5—Annual and average VMP's and MIRR's of public wood-preserving research

	Social discount rate					
	Multiplier = 0.12			Multiplier = 0.18		
Year	0.04	0.07	0.10	0.04	0.07	0.10
			Dollars[1]			
1950	1.02	0.98	0.94	0.69	0.66	0.64
1951	.84	.80	.77	.56	.54	.52
1952	.86	.83	.80	.58	.56	.54
1953	.82	.79	.76	.55	.53	.51
1954	.77	.74	.71	.52	.50	.48
1955	.76	.73	.70	.51	.49	.47
1956	.58	.56	.54	.39	.37	.36
1957	.47	.45	.44	.32	.31	.29
1958	.35	.34	.32	.24	.23	.22
1959	.36	.35	.33	.24	.23	.22
1960	.38	.37	.35	.26	.25	.24
1961	.27	.26	.25	.18	.18	.17
1962	.21	.21	.20	.14	.14	.13
1963	.21	.20	.19	.14	.13	.13
1964	.20	.20	.19	.14	.13	.13
1965	.20	.19	.19	.14	.13	.13
1966	.25	.24	.23	.17	.16	.15
1967	.25	.24	.23	.17	.16	.15
1968	.25	.24	.23	.17	.16	.16
1969	.21	.20	.20	.14	.14	.13
1970	.30	.28	.27	.20	.19	.18
1971	.22	.21	.20	.15	.14	.14
1972	.21	.21	.20	.14	.14	.13
1973	.24	.23	.22	.16	.16	.15
1974	.39	.38	.36	.26	.25	.24
1975	.34	.33	.32	.23	.22	.21
1976	.24	.23	.23	.16	.16	.15
1977	.25	.24	.23	.17	.16	.15
1978	.32	.30	.29	.21	.20	.20
1979	.38	.26	.25	.18	.18	.17
1980	.46	.44	.42	.31	.29	.28
Average VMP	.35	.34	.32	.24	.23	.22
MIRR		< 0 (average VMP at zero discount rate = 0.37)			< 0 (average VMP at zero discount rate = 0.25)	

[1]1967 dollars.

4. Davis, J. "A Comparison of Procedures for Estimating Returns to Research Using Production Functions," *Australian Journal of Agricultural Economics*. Vol. 25, No. 1, 1980, pp. 60-72.

5. Griliches, Z. "Research Expenditures, Education, and the Aggregate Agricultural Production Function," *American Economic Review*. Vol. 54, No. 6, 1964, pp. 961-74.

6. ———. "Issues in Assessing the Contribution of Research and Development to Productivity Growth," *Bell Journal of Economics*. Vol. 10, No. 1, 1979, pp. 92-116.

7. Jakes, P.J. "Research Evaluation in the U.S. Forest Service: Opinions of Research Managers," *Research Policy*. Vol. 17, No. 5, 1988, pp. 283-92.

8. Lyu, S-J., F. White, and Y-C. Lu. "Estimating Effects of Agricultural Research and Extension Expenditures on Productivity: A Translog Production Function Approach," *Southern Journal of Agricultural Economics*. Vol. 16, No. 2, 1984, pp. 1-8.

9. Mansfield, E. *The Economics of Technological Change*. New York: Norton, 1968.

10. National Science Foundation. *Research and Development in Industry*. Various issues. Washington, DC.

11. Peterson, W.L. "Returns to Poultry Research in the United States," *Journal of Farm Economics*. Vol. 49, No. 3, 1967, pp. 656-69.

12. Ruttan, V.L. "Agriculture Research and the Future of American Agriculture," *The Future of*

American Agriculture as a Strategic Resource. (S.S. Batie and R.G. Healy, eds.) Washington, DC: The Conservation Foundation, 1980.

13. Seldon, B.J. "Economic Analysis of Forestry Research: Synthesis and Methodology," *Evaluating Agricultural Research and Productivity.* (W.B. Sundquist, ed.) Misc. Pub. 52-1987, St. Paul: Minn. Agr. Exp. Sta. & Univ. of Minn., 1987.

14. ______. "A Nonresidual Estimation of Welfare Gains from Research: The Case of Public R&D in a Forest Product Industry," *Southern Economic Journal.* Vol. 54, No. 1, 1987, pp. 64-80.

15. Sonka, S.T., and D.I. Padberg. *Estimation of an Academic Research and Development Price Index.* Agr. Econ. Bull. 79 E-100, Urbana: Univ. of Illinois, 1979.

16. U.S. Department of Commerce, Bureau of Census. *Statistical Abstract of the United States: 1984.* 1984.

17. U.S. Department of Commerce. *Census of Manufactures, Industry Series: Wooden Containers and Miscellaneous Wood Products.* Various years.

18. U.S. Government Printing Office. *Economic Report of the President.* 1987.

19. White, F., and J. Havlicek. "Optimal Expenditures for Agricultural Research and Extension: Implications of Underfunding," *American Journal of Agricultural Economics.* Vol. 64, No. 1, 1982, pp. 47-55.

What Does Performing Linear Regression on Sample Survey Data Mean?

Phillip S. Kott

Abstract. *Most economists understand linear regression as the estimation of the parameters of a linear model. There are two other ways of interpreting the results of linear regression, however, and most software packages designed specifically to handle data from complex sample surveys (for example, SURREGR and PC CARP) assume one of these interpretations. This article contrasts the conventional model-based theory of linear regression to the design-based theories underlying survey-sampling software. The article demonstrates how procedures from design-based regression theory can be justified and exploited in a linear model framework. Proposed is a test for comparing the results of ordinary least squares and weighted regression.*

Keywords. *Design-based, model-based, random sample, mean-squared error.*

An economist usually thinks of linear regression as a means of estimating the parameters of a preconceived linear model or of testing the validity of a particular model within a continuum of slightly more general linear models.

Many survey statisticians, though, have a different view of linear regression. They are interested in describing characteristics of a finite population. To this end, ordinary least squares regression performed on multivariate data from the entire population can produce some useful summary statistics. In practice, however, it is too difficult to obtain information from the entire population, and so, data is obtained from a sample of observations. (The term "observation" will be used to refer to any member of the population under study even though relevant values for nonsampled members are not actually observed.)

The economist's view of linear regression as given above is called "model-based," the survey statistician's view "design-based" (*4*).[1]

According to model-based theory, part of the multivariate data—the dependent variable—is itself a random variable generated by a stochastic mode. Orthodox design-based theory, in contrast, holds that all the data are fixed; the only thing probabilistic is the selection process that randomly chooses some observations for the sample and not others. There is no model generating the data, only a useful way to summarize the covariation of multivariate values in the finite population.

There is an alternative school of thought in design-based theory that we will call the "Fuller School" (*1*, *2*). This theory says that although there is indeed an underlying model generating the data, the analyst knows little about this model. In fact, the relationship among the variables may not even be linear. Linear regression is simply a means of summarizing in linear fashion a relationship among the multivariate values generated by the model.

Several software packages perform linear regressions and estimate variances in accordance with the Fuller School, which is more palatable to economists than the orthodox design-based approach. Two popular packages are SURREGR (*5*) and PC CARP (*3*).

The Standard Linear Model and the Sample

Suppose the multivariate values of a population of M observations can be fit by the linear model:

$$y = X\beta + \epsilon, \tag{1}$$

where:

- $y = (y_1, \ldots, y_M)'$, is an $M \times 1$ vector of population values for a dependent variable;
- X is an $M \times K$ matrix of population values for K independent variables or regressors;
- β is a $K \times 1$ vector of regression coefficients; and
- ϵ is an $M \times 1$ vector of disturbances or errors satisfying $E(\epsilon) = 0$, and $Var(\epsilon) = E(\epsilon\epsilon') = \sigma^2 I_M$.

If one knew y and X, then the best linear unbiased estimator of β would be the ordinary least squares (OLS) estimator:

$$B = (X'X)^{-1}(X'y). \tag{2}$$

But, y and X values are known only for a sample of m observations which has been selected at random in a manner assumed to be independent of ϵ.

The best (minimum variance) linear unbiased estimator of β, given the sample, is:

$$b_{OLS} = (X'SX)^{-1}(X'Sy), \tag{3}$$

where S is an $M \times M$ diagonal matrix of zeroes and 1's. The ith diagonal of S is 1 if and only if the ith unit of the population is in the sample. Observe that S in

Kott is special assistant for economic survey methods in the Office of the Director, Bureau of the Census, and was senior mathematical statistician with the Survey Research Branch, National Agricultural Statistics Service.

[1]Italicized numbers in parentheses cite sources listed in the References at the end of this article.

equation 3 allows only those rows of X and elements of y containing information from sampled observations to be captured in b_{OLS}.

The variance of b_{OLS} (a variance-covariance matrix) is $\sigma^2(X'SX)^{-1}$. An unbiased estimator for this variance can be determined by estimating σ^2 in the above expression by $s^2 = (y - Xb_{OLS})'S(y - Xb_{OLS})/(m - K)$.

The Design-Based Approaches

In the orthodox design-based approach to regression, there is no underlying linear model. The goal of linear regression is not to estimate β in equation 1. Rather, it is to estimate B in equation 2 based on a randomly selected sample of m observations.

Let P be an M × M diagonal matrix, the ith diagonal of which is the probability that unit i was selected for the sample. We can call $W = (m/M)SP^{-1}$ the matrix of sampling weights. Note that W = S when every unit has a probability of selection equal to m/M.

For many sampling designs, the weighted regression estimator,

$$b_W = (X'WX)^{-1}(X'Wy), \tag{4}$$

is a design-consistent estimator of B in equation 2. That is, as m (and M) grows arbitrarily large, $b_W - B$ has a probability limit of zero with respect to the probability space generated by the sampling mechanism.

Fuller (*1*) points out that b_W is generally a consistent estimator of $B^* = Q^{-1}R$, where $Q = \lim_{M \to \infty} (X'X)/M$ and $R = \lim_{M \to \infty} (X'y)/M$ when Q^{-1} and R exist and b_W is a consistent estimator of B. Often B is referred to as the finite population regression parameter, while B* is the infinite population regression parameter.

What we have called the Fuller School of linear regression assumes the existence of a model generating the finite population data, but not assuming very much about the nature of that model, only that Q^{-1} and R exist. This theory employs the laws of probability in the same way as the orthodox design-based school does: exclusively through the sample selection process.

The model-based estimator, b_{OLS}, equals the design-based estimator, b_W, when W = S (that is, when all the sampled observations have equal probabilities of selection). If the model in equation 1 holds, then the infinite population regression parameter, B*, will equal the model regression parameter, β.

Design Mean-Squared Error Estimation

To estimate the mean-squared error of b_W as an estimator of either B or B* under the sampling design, we need to know more about the design.

Suppose the population of M observations is divided into L strata (L may equal 1). And, suppose that there are $n_h \geq 2$ distinct primary sampling units (which may involve clusters of the actual observations) selected from stratum h. Ultimately, m_{hj} (which may also equal 1) observations are selected for the sample from the primary sampling unit (PSU) hj. This broad framework allows for multistage random sampling with (perhaps) unequal selection probabilities at each stage. For simplicity, however, we exclude from consideration samples where some PSU has been selected more than once in the first sampling stage.

Without loss of generality, b_W can be rewritten as $b_W = Cy^*$, where y* is an m vector containing only those members of y that correspond to sampled observations and C is the m corresponding columns of $(X'WX)^{-1}X'W$. Let r* be the vector of residuals analogous to y* (note: $r = y - Xb_W$).

For every sampled PSU hj, define D_{hj} as an m × m diagonal matrix of 1's and zeroes such that the ith diagonal of D_{hj} is 1 only if the ith member of y* corresponds to an observation in PSU hj. Finally, let $g_{hj} = CD_{hj}r^*$.

The linearization (or Taylor Series linearization or delta method) mean-squared error estimator for b_W as an estimator of B* is the matrix:

$$\text{mse} = \sum_{h=1}^{L} \frac{n_h}{n_h - 1} \left[\sum_{j=1}^{n_h} g_{hj}g_{hj}' - \frac{1}{n_h} \left(\sum_{j=1}^{n_h} g_{hj}\right) \left(\sum_{j=1}^{n_h} g_{hj}\right)'\right]. \tag{5}$$

This estimator is computed by the SURREGR software packages. PC CARP scales mse by {(m–1)/(m–K)}. Either way, the result is a consistent estimator of design mean-squared error (in the Fuller School sense) as $n = \sum n_h$ grows arbitrarily large under mild conditions (*8*). (Orthodox design-based theory can require finite population correction terms which are unavailable in SURREGR and suppressible in PC CARP.)

The Law of Large Numbers and the Central Limit Theorem can often be invoked to test hypotheses of the form $HB^* = h_0$, where H is an r × K matrix and $r \leq K$. Under the null hypothesis,

$$T^2 = (Hb_W - h_0)' (H\{\text{mse}\}H')^{-1}(Hb_W - h_0) \tag{6}$$

has an asymptotic chi-squared distribution with r degrees of freedom. When n – L – K is not large, a common *ad hoc* alternative to T^2 is $F = T^2/r$, which is assumed to have an F distribution with r and either n – L –K (SURREGR) or n – L (PC CARP) degrees of freedom.

The Extended Linear Model

The use of b_W from equation 4 and mse from equation 5 can be justified in a purely model-based context. This is done by extending the linear model in equation 1 to allow for the possible existence of missing regressors and the likelihood that $Var(\epsilon)$ is much more complicated than $\sigma^2 I_M$. The proofs for the assertion made in this section and other technical details are in (*6*).

Suppose the multivariate values of the population of M observations can be fit by the linear model:

$$y = X\beta + z + \epsilon, \tag{7}$$

where y, X, β, and ϵ are unchanged except that $Var(\epsilon)$ need not equal $\sigma^2 I_M$. The new vector z satisfies $\lim_{M \to \infty} X'z/M = 0$, and is a composite of all the regressors in a fully specified model for y that are otherwise missing from equation 7 and the joint effect of which on y cannot be captured within $X\beta$.

Under mild conditions, b_W is nearly (that is, asymptotically) unbiased under the model in equation 7 (as n grows large). The same cannot be said for b_{OLS} unless $\lim_{M \to \infty} X'Pz/m = 0$, which in practical terms means that the probabilities of selection are unrelated to the missing regressors.

The expression in equation 5 is a nearly unbiased estimator of the model mean-squared error of b_W under many sampling designs and variance matrices for ϵ. The only restriction on the latter is that $E(\epsilon_i \epsilon_{i'})$ be zero when i and i' are sampled observations from different PSU's and bounded otherwise. This restriction is very mild since any covariation among observations across PSU's should, in principle, be captured by X or z.

The problem with b_W and mse from a model-based point of view is that they are not very efficient. For example, when z in equation 7 is identically zero and $Var(\epsilon) = \sigma^2 I_M$, the variance of b_{OLS} will be less than that of b_W.

Even if $Var(\epsilon) \neq \sigma^2 I_M$, b_{OLS} is unbiased when $z \equiv 0$. Moreover, b_{OLS} may still be more efficient than b_W. With the g_{hj} in equation 5 appropriately redefined, mse could serve as an estimator of the variance of b_{OLS} under a fairly general specification for $Var(\epsilon)$. More efficient and also nearly unbiased is the matrix,

$$mse' = \frac{n}{n-1} \sum_{h=1}^{L} \sum_{j=1}^{n_h} g_{hj} g_{hj}', \tag{8}$$

which equals mse when L = 1. It is a simple matter to get SURREGR and PC CARP to produce b_{OLS} and either mse' (SURREGR) or $\{(m-1)/(m-K)\}$mse' (PC CARP).

Although mse' (and mse for that matter) is an estimator for the variance of the estimated regression coefficient when $z \equiv 0$, we retain the "mse" notation for convenience.

Whether b_W or b_{OLS} is calculated, the test statistic in equation 6 can be employed (with b_{OLS} replacing b_W and perhaps mse' replacing mse as appropriate) to test hypotheses of the form $H\beta = h_0$.

An Example

Consider the following example synthesized from USDA data from the National Agricultural Statistics Service's June 1989 Agricultural Survey. In a particular State, 17 primary sampling units were selected from among 4 strata. These PSU's were then subsampled yielding a total sample of 252 farms. Although the sample was random, not all farms had the same probability of selection.

We are interested in estimating the parameters, β_1 and β_2, of the following equation:

$$y_i = x_{1i}\beta_1 + x_{2i}\beta_2 + z_i + \epsilon_i, \tag{9}$$

where i denotes a farm,

y_i is farm i's planted corn-to-cropland ratio when i's cropland is positive, zero otherwise;

x_{1i} is 1 if farm i has positive cropland, zero otherwise; and

x_{2i} is farm i's cropland divided by 10,000.

Dropping all sampled farms with zero cropland from the regression equation will have no effect on the calculated values $b_{1 \cdot W}$ and $b_{2 \cdot W}$ (or $b_{1 \cdot OLS}$ and $b_{2 \cdot OLS}$). It would, however, affect mse (and mse') if none of the subsampled farms from a particular PSU had cropland. Although this phenomenon does not occur here, it does raise an issue worthy of a brief digression.

Sometimes an economist needs to perform a regression on a subset of a sample. In those circumstances, one may need to worry about the impact on mse when no member of the subset comes from a particular PSU. This problem can be avoided by treating all the originally sampled observations as if they were in the regression data set. Those observations not in the subset under study could be assigned y and x values equal to 0.

The results of performing both OLS and weighted regression on the data in our example are displayed in table 1. The table contains estimated root mean-squared errors computed from the appropriate diagonal elements of mse and mse'. Also displayed is $\sqrt{mse_0}$: the estimated coefficient root mean-squared error assuming that $z \equiv 0$ and that there is no correlation across observations within PSU's. The variance matrix mse_0 is simply mse' calculated as if there were 252 PSU's. The ACOV option of PROC REG in the popular programming language SAS (*7*) used along with a weight statement will approximately yield this number

(the value from ACOV needs to be multiplied by m/(m–1) for strict equality).

The ratio of mse'/mse_0 is a measure of the effect of correlated errors within PSU's on the mean-squared error of an estimated regression coefficient. This ratio will be greater than 1 when there is such a cluster effect. Similarly, the ratio mse/mse' is a measure of the effect of stratification on the mean-squared error of an estimated regression coefficient. This ratio should be less than 1 when there is such a stratification effect.

There can be cluster effects even when $z \equiv 0$, while there are stratification effects only when z_i values vary across strata. We can see from table 1 that there are generally much more pronounced cluster effects than stratification effects (if any).

A Test

Table 1 reveals that the OLS regression coefficients are more efficient (that is, have smaller mse and mse' values) than the weighted regression coefficients. It remains to test whether these two sets of coefficients are really estimating the same thing. If that is the case, then the OLS estimates are clearly superior.

One general way to test whether b_{OLS} and b_W are estimating the same parameter vector, β, is to replace y in equation 4 by $y^e = (y', y')'$, X by:

$$X^e = \begin{bmatrix} X & X \\ X & 0 \end{bmatrix},$$

and W by:

$$W^e = \begin{bmatrix} W & 0 \\ 0 & W \end{bmatrix}.$$

The resulting estimator is $b^e_W = (b_{OLS}', d')'$ where $d = b_W - b_{OLS}$. Calculating mse^e is done in a manner analogous to mse in equation 5. In calculating mse^e, the elements of y^{e*} correspond to observations coming from the same number of PSU's (and strata) as do the elements of its analogue, y^*.

The test statistic in equation 6 can be invoked to test whether d is significantly different from zero (with b^e_W replacing b_W and mse_e replacing mse). This was done for the data set examined in the previous section. The resultant value for T^2 was 5.07. If T^2 is assumed to have a chi-squared distribution with two degrees of freedom, the null hypothesis was not rejected (that b_{OLS} and b_W are estimating the same thing) at the 0.05 significance level but would be rejected at the 0.1 level. Assuming $T^2/2$ has an F distribution with 2 and 13 (17 PSU's minus 4 strata) degrees of freedom, the null hypothesis would not be rejected even at the 0.1 level.

If one's primary concern is robustness to the possible existence of a z vector related to the sampling weights rather than the efficiency of the estimated regression coefficients, then the fact that the test statistic exceeds its expected value under the null hypothesis (2 if T^2 is chi-squared) would be reason enough to prefer b_W over b_{OLS}.

Fuller (*2*, p. 106, equation 17) proposed a different test for determining whether the difference between b_W and b_{OLS} is significant. His test assumed that the errors were independent and identically distributed across observations which is clearly not the case in our example.

Table 1— Estimated regression coefficients and root mean-squared error estimates

Estimated regression coefficient	Estimate	$\sqrt{mse}$	$\sqrt{mse'}$	$\sqrt{mse_0}$
$b_{1.W}$	0.3363	0.0822	0.0781	0.0301
$b_{2.W}$	.8636	1.2389	1.3008	.4764
$b_{1.OLS}$	.4460	.0396	.0440	.0192
$b_{2.OLS}$	–.8791	.4637	.4651	.1688

References

1. Fuller, W.A. "Regression Analysis for Sample Survey," *Sankhya*. Ser. C, 37, 1975, pp. 117-32.

2. ______. "Least Squares and Related Analyses for Complex Survey Designs," *Survey Methodology*. Vol. 10, 1984, pp. 97-118.

3. Fuller, W.A., W. Kennedy, D. Schnell, G. Sullivan, and H.J. Park. *PC CARP*. Ames: Iowa State University, Statistical Laboratory, 1986.

4. Hansen, M.H., W.G. Madow, and B.J. Tepping. "An Evaluation of Model-Dependent and Probability-Sampling Inferences in Sample Surveys," *Journal of the American Statistical Association*. Vol. 78, 1983, pp. 776-93.

5. Holt, M.M. *SURREGR: Standard Errors of Regression Coefficients from Sample Survey Data*. Research Triangle Park, NC: Research Triangle Institute, 1977.

6. Kott, P.S. "A Model-Based Look at Linear Regression with Survey Data," *American Statistician*, forthcoming.

7. SAS Institute. *SAS User's Guide: Statistics, Version 5 Edition*. Cary, NC: SAS Institute, 1985.

8. Shah, B.V., M.M. Holt, and R.E. Folsom. "Influence About Regression Models from Sample Survey Data," *Bulletin of the International Statistical Institute*. Vol. 47, 1977, pp. 43-57.

The Long-Term Adequacy of World Timber Supply. *By Roger A. Sedjo and Kenneth S. Lyon. Washington, DC: Resources for the Future, 1990, 245 pages, $30.*

Reviewed by Jan K. Lewandrowski

Are we taking too much timber from the world's forests? Will high prices for forest products prohibit construction of your dream house? No, say Roger Sedjo and Kenneth Lyon, who present a strong rebuttal to the common belief that, over the next few decades, decreasing forest inventories and rising world demand for forest products will substantially increase real timber prices.

No major increase in the scarcity of timber for the foreseeable future is the conclusion the authors have drawn from a series of 50-year simulations of their Timber Supply Model (TSM). The TSM is the first economic model of the world's timber supply, and with it, Sedjo and Lyon have made a major contribution to forest economics. The model is motivated by a structural change, now in progress, that is fundamentally altering the way in which today's market economies utilize forests. In the past, trees have been "gathered" from stands of old growth; in the future they will be "harvested" on managed tree farms and plantations.

Throughout the world's timber-producing regions, this structural change is raising numerous issues that will have to be addressed by forest owners, public policymakers, and societies in general. How fast should old-growth inventories by drawn down? What are the longrun regional implications of preserving particular areas of old growth? Where should new investments in forest regeneration be most (least) intense? How might a major technological breakthrough in forest regeneration, or the entry of a major new supply region influence the current structure of world timber production? These are the types of questions that can be analyzed systematically, on a global scale, by using the Timber Supply Model.

Conceptually, the setup of the TSM is straightforward. The world is divided into eight major supply regions. Seven regions—the U.S. Pacific Northwest, the U.S. South, western Canada, eastern Canada, Asia-Pacific, Nordic Europe, and an "emerging region" (Brazil, Chile, Venezuela, Australia, New Zealand, South Africa, Spain, and Portugal)—are modeled as price responsive. The eighth supply region, the rest of the world (essentially the Soviet Union), is treated as price unresponsive. The price-responsive regions are further divided into 22 land classes, which are the producing units in the model. For each land class, a production function and a cost function are developed. The production functions reflect, for each class, its location, accessibility, area, growth-yield relationships for the dominant species, existing inventories of trees as well as their age distribution, and silvacultural response to investments in regeneration. The cost functions include access costs, logging and mill transportation costs, and regeneration costs.

The 22 producing units supply the global timber market. The aggregate world demand curve for timber, however, is derived outside of the TSM. To fix its initial location (that is, in year 0), Sedjo and Lyon "choose" the slope and intercept so as to yield "reasonable" prices and demand elasticities in the simulations. The values chosen for these parameters are provided, but, in one small criticism of their work, I believe more should have been said about the selection criteria. Estimates of the future growth rate of timber demand were developed subjectively based on a quantitative assessment of historical timber price and consumption data and on a qualitative assessment of future levels of population growth, market saturation, and technological change.

Given the exogenous level and growth rate of demand, the TSM maximizes the discounted present value of the time stream of net surplus (consumers' plus producers') resulting from global timber harvests over a 50-year period. Five sets of simulations are reported, each incorporating different assumptions concerning the future levels of variables that are exogenous to the TSM but which, at least conceptually, affect regional timber harvests. The future scenario considered most likely to occur, in the authors' opinion, is termed the base case. The four alternative scenarios vary the base case assumptions concerning the future levels of world exchange rates, Soviet Union timber harvests, new forest plantation establishment, and tax incentives on timber regeneration in the United States.

The TSM solution includes time paths for the world timber price, regional timber harvests, and regional investments in forest regeneration. In the model, harvest levels can be affected by changes in rotation lengths, the rate of old-growth cutting, the number of land classes in production, the level of forest regeneration, technological improvements in growing trees, and the rate at which new timber plantations are established. Many simplifying assumptions were necessary to accommodate the available data and to provide forecasts of the variables that are exogenous to the TSM. In general, Sedjo and Lyon defend their assumptions convincingly. Still, many of the simplifications, inevitably, come down to a judgment call, and

Lewandrowski is an agricultural economist with the Resources and Technology Division, ERS.

there are instances where their judgment will be questioned. For instance, I would take issue with their assumption that the establishment of new industrial forest plantations in the emerging region occurs at a fixed rate (in the base case, 200,000 hectares per year for the first 30 years). The emerging region is modeled as price responsive and its harvest levels are determined endogenously. But, these harvests are assumed to come exclusively from plantation forests. Hence, the establishment of new plantations directly determines future harvest levels. The decision to establish new plantations in the emerging region should be endogenous because, conceptually, it is the same as the decision to invest in forest regeneration in the other regions.

I do not believe there will be much criticism of the structure of the TSM. Rather, different people will take issue with the ways in which different parameters were estimated, or with the assumptions employed to set the future levels of the various exogenous variables. These types of criticisms call into question only the results of the reported simulations. They do not relate to the forecasting ability of the TSM. The TSM can be adapted to allow for almost any set of assumptions regarding the model's parameters and the future time paths of the exogenous variables.

This book will be most valuable to forest economists and readers with an interest in economic applications of optimal control theory. One need not, however, have a background in either of these areas to find the book useful. Someone with an interest in timber policy can get a layman's presentation of the model in chapter 4 and then skip to chapters 8 and 9 for a readable discussion of the various simulation results. A technician may be more interested in the actual workings of the model than with its applications. How were the regional yield functions developed? How was technical change incorporated? What measure of the world timber price is actually being solved for? The technical details of the TSM are clearly laid out in chapter 7 and appendices A through O. For a researcher who needs data on the world's forest assets, the appendices may be a good source. One real strength of the book is its presentation. Readers can easily identify sections that interest them and can ignore the rest without missing much.

Sedjo and Lyon have also laid the foundation for a substantial body of future research. Disaggregating world timber demand into regional demand functions would allow the TSM to analyze timber trade issues. This disaggregation would also encourage an analysis of how major consuming regions, such as the United States or Japan, might respond to offset anticipated negative impacts resulting from longrun shifts in the regional supplies of timber.

The framework might also be adapted to look at forest use issues in areas that are not important to the world's industrial wood market. About 50 percent of the world's wood harvest is used for fuelwood and most of this is cut in tropical forests. In other areas of the tropics, large tracts of forests are being cleared for agriculture. The conclusion that the supply of industrial timber is safe for the foreseeable future does not imply that concerns relating to the longrun stability of the world's other forests are unfounded. But, aside from the Asia-Pacific region of the TSM, tropical forests produce very little industrial wood. So, in the context of this study, tropical deforestation is not expected to have a major impact on the world's timber supply. Still, the processes driving forest clearing in the tropics are dynamic and can be conceptualized and modeled in a control framework.

In summary, Sedjo and Lyon have succeeded in developing a new and conceptually complete model of the world's timber supply. They have used the model to tell a convincing story. The story is that, for the next 20 to 30 years, the world's industrial forests will be stable in the aggregate and that major increases in the real price of timber are unlikely. Timber production, however, will shift back and forth among the major producing regions. There will also be a movement toward managed tree farms accompanied by a drawing down of old-growth stocks. So while you may never be able to afford that dream house, the cause won't be the high cost of timber.

Agricultural Trade and the Big Bang

The International Politics of Agricultural Trade: Canadian-American Relations in a Global Agricultural Context. *By Theodore H. Cohn. Vancouver, B.C., Canada: University of British Columbia Press, 1990, 280 pages, $36.95.*

Reviewed by William R. Wilson

Paraphrasing, albeit loosely, the sometimes prophetic Andy Warhol—everything has its brief period of public exposure. Agricultural trade is experiencing its period of exposure. Recently, the Uruguay Round of the General Agreement on Tariffs and Trade produced global visibility for agricultural trade and the limitations of existing international institutions. An impressive effort among technocrats and bureaucrats across many nations continues the pursuit of an international regime to encourage an economically rational allocation of the agricultural factors of production. Cohn's book is a case study of how the North American agricultural market and related institutions responded to binational and international pressures during 1950-90.

The book is almost entirely descriptive. Quantitative techniques are limited to value, volume, and trend figures for trade flows, and although this may prove to be initially disconcerting to many economists trained in the past two decades, the wealth of well-documented information should assuage the anxiety and reward the reader amply. This Galbraithian-type of book harkens back to the political economy bent of the discipline.

The author structures the examination of 40 years of Canada-U.S. agricultural trade within a paradigm of four dependent variables—conflict, cooperation, trade strategies, and market power—and a collection of environmental and agricultural explanatory variables. For example, Cohn musters historical evidence to support the hypothesis that Canada-U.S. cooperation and conflict in marketing wheat was influenced by global supply, competition, the U.S. trade balance, relative economic size and agricultural economies, national security objectives, and the strength of existing trade institutions. Cohn says that the asymmetrical interdependence of the Canada-U.S. trading relationship, factoring in the prevailing U.S. national objectives, often led to unilateral U.S. action. Canada, with its dependence on access to the U.S. market and limited fiscal capabilities, was typically seeking U.S. or multilateral cooperation. The analysis emphasizes Canada-U.S. wheat-marketing competition through international pricing, surplus disposal, export subsidy, and credit vehicles. Except for the expanded commodity discussion on agricultural trade barriers, wheat is used as a proxy for all agricultural commodities. While the proxy serves to accommodate a comprehensible product, the representativeness of wheat is problematic due to fundamental differences in North American marketing of other major products such as oilseeds and meats.

The book briefly discusses the Canada-U.S. Trade Agreement signed in January 1989, after previous attempts at bilateral trade arrangements in 1911 and 1948 were aborted by Canada. Cohn notes that Canada was again seeking assured access to the U.S. market but that "... some Canadian policy makers were rather naive since the U.S. would not relinquish the right to retaliate with trade relief actions and other measures ... [where believed warranted]." Indeed, the amendments to U.S. trade law immediately preceding the bilateral agreement with Canada strengthened U.S. market protection from identified export practices, including those of Canada. Cohn contends that the U.S. rationale for the bilateral trade deal and the inclusion of agriculture was largely to generate multilateral visibility for reduced agricultural trade barriers. No mention is made of assured future access to Canada's freshwater resources, an issue which threatened to derail Canadian support for the agreement. Some researchers maintain that U.S. access to Canadian water remains unsettled and unsettling.

There are numerous bits of information throughout the book which will spark the interest of the reader. For example, the early U.S. contribution to agricultural protectionism is interesting. The U.S. insistence on special GATT treatment for agricultural trade is reflected in Article XI. GATT calls for the elimination of quantitative import restrictions, but includes provision for the implementation of such restrictions against agricultural imports as a complement to a domestic program intended to restrict production or remove a surplus. The import restriction capability was strengthened by a 1955 waiver allowing U.S. farm import quotas in the absence of concomitant domestic supply measures. The ability of trade negotiators to challenge the restrictive policies of Japan and the European Community is greatly influenced by these same provisions.

Cohn concludes that the abundance of controversy over the agricultural provisions included within the Canada-U.S. Trade Agreement demonstrates the difficulty of reforming world agriculture in the GATT. Considering the magnitude of agricultural transfers, as estimated in the form of producer subsidy equivalents by the Organization for Economic Cooperation and Development—$62 billion in the EC, $39 billion in the United States, $37 billion in Japan, and $7 billion in Canada—agricultural trade liberalization may be limited to hard-fought, small-caliber pops, like the 1960's expiration of the Canada-U.S. wheat duopoly, rather than a big bang.

Wilson is an economist, Pacific Forestry Centre, Forestry Canada, Victoria, British Columbia.

Unilateral Liberalization: A Rare Experiment

Farming Without Subsidies: New Zealand's Recent Experience. *Edited by Ron Sandrey and Russ Reynolds. Wellington, New Zealand: Ministry of Agriculture and Fisheries, 1990, 347 pages, $29.50.*

Reviewed by Nancy Morgan

Since 1984, a comprehensive economic reform program has transformed the New Zealand agricultural sector from one highly dependent on government assistance and intervention to one that is market-oriented. This deregulation of the New Zealand economy and liberalization of its trade provides economists with a unique opportunity to observe and analyze the re-emergence of market forces and the adjustment process of farms and agribusinesses. The publication of this book is a culmination of 6 years of experience since the election of the Labor Government in 1984 and the advent of "Rogernomics," the popular word for the economic policy approach of Roger Douglas, New Zealand's Minister of Finance until December 1988.

The indepth analysis of the New Zealand experience in the context of economywide policy reform is particularly timely as the deadline for the General Agreement on Tariffs and Trade (GATT) is renegotiated, and interest is sparked by options to the multilateral reform process.

This book traces the context, changing policies, and consequences of economic reform carried out in New Zealand from 1984 to 1989, documenting the effect of the reforms on the agricultural sector. The sensitive issue of agricultural reform and the experiences of a country that has unilaterally removed all specific agricultural subsidies within the context of economywide reforms should interest readers ranging from farmers to politicians. While the book is general enough to appeal to a broad audience, it contains enough economic rigor to interest economists and policymakers. The format of the book enhances its readability, allowing readers to select specific areas of interest. A comprehensive summary at the beginning establishes a context within which the reader feels at ease.

The overall structure of the book is comprehensive and easy to follow. Moving from a discussion of the historical context of change, to the reforms themselves, and then to their consequences, the book provides the reader with an overview of the effects of economic reform on the agricultural sector in general, land and labor markets, agribusiness, and the marketing and processing sectors. Chapter seven, "Deregulation: Selected Case Studies," furnishes a strong analysis of the effects of liberalization on three separate New Zealand agricultural industries: the egg, wheat, and fluid milk sectors.

Perhaps the weakest section in the book is the final one, entitled "Future," which consists of three chapters: "The Competitiveness of Agriculture," "Future Prospects, 1990-1995," and "Issues for Policy Makers." The issue of competitiveness is a crucial one, of great interest to readers concerned about the effects of unilateral liberalization and how it influences the economy. Containing useful information about the tools used to measure competitiveness, the chapter focuses more on the intersectoral terms of trade between the tradeable and nontradeable sectors in New Zealand over the past decade than how the liberalization process affected the international competitiveness of the agricultural sector. The reader comes away with an understanding of why the agricultural sector performed poorly over the past two decades and the importance of the appropriate policy mix on the real exchange rate and the enhancement of the tradeable sector. However, the status of future competitiveness in light of global changes is very unclear. Perhaps if this chapter had been placed in a different section, such as "Consequences" rather than "Future," the reader would not come away with a feeling of mild confusion and unfulfilled expectations.

The next chapter concludes that reducing agricultural assistance has allowed the market to determine the appropriate levels of production in competing pastoral enterprises, such as deer and goats. Hence, New Zealand enters the 1990's with a more diversified pastoral base that reduces exposure of agriculture to adverse commodity price shocks. The relevance of this chapter would perhaps be enhanced if the concept of competitiveness were expanded and analyzed in the context of the forecasts.

The general conclusions, elaborated in the final chapter, are that while the original reforms envisioned in 1984 included a reduction in assistance to all sectors of the economy, the agricultural sector has borne the brunt of the burden of reform. Incomes of agricultural producers were immediately hurt by the elimination of direct assistance to agriculture, while hikes in interest rates aggravated the precarious financial situation of some farmers. Farmland values fell precipitously, by over 60 percent in real terms between 1982 and 1989.

This concluding chapter, "Issues for Policy Makers," summarizes the findings of the previous essays while outlining the steps that need to be taken to complete the reform process. Despite reform rhetoric, protection continues for import-competing industries, resulting in higher input costs for farmers. The

Morgan is an agricultural economist with the Agriculture and Trade Analysis Division, ERS.

competitiveness of the agricultural sector continues to be hampered by high input costs and by high costs in the processing sector resulting from labor inefficiencies.

Publications that are a compilation of papers by different authors often lack continuity and clarity of tone and style. The editor should be commended for producing a readable book. Each chapter is focused, yet integrated into the book's theme, which is to provide the reader with an understanding of the consequences of New Zealand's unilateral liberalization experience. Although the book succeeds in establishing benchmarks for ongoing reforms necessary to ensure the full potential of the agricultural sector, the reader is left unclear about the future of the sector and the overall effects of unilateral liberalization on such issues as international competitiveness and economic welfare.

Much research has been conducted on the effects of multilateral liberalization. However, not much is known of the actual effects of unilateral liberalization on developed countries. Thus, this study, for proponents of free trade, while not providing ammunition to promote the free trade cause, provides valuable documentation on the process and consequences of unilateral economic reform. The book is useful for policymakers who are interested in the effects of policy mixing on specific sectors of the economy. However, New Zealand's situation as a small country may make the unilateral liberalization experience less relevant to countries like the United States, where general standards of living are not inexorably linked to the performance of the trade sector in general and agriculture specifically.

The book includes: (1) "The Seeds of Change" by Tony Rayner; (2) "Agricultural Trade" by Ralph Lattimore and Allan Rae; (3) "The Macroeconomic Environment" by Richard Wallace; (4) "Assistance to Agriculture " by Laurence Tyler and Ralph Lattimore; (5) "Primary Sector Taxation Reform" by John King; (6) "The Regulatory Environment" and (7) "Deregulation: Selected Case Studies" by Ron Sandry; (8) "Farm Prices and Costs" by Russell Reynolds and Walter Moore; (9) "How Farmers Responded" by Russell Reynolds and S. SriRamaratnam; (10) Land Markets and Rural Debt" by Warren Johnston and Ron Sandrey; (11) Rural Employment and Labour Adjustments" by John Savage; (12) "How Agribusiness Responded" by Bill Dobson and Allan Rae; (13) "Marketing and Processing" by Tony Zwart and Walter Moore; (14) "The Competitiveness of Agriculture" by Russell Reynolds; (15) "Future Prospects, 1990-1995" by Richard Wallace and Russell Reynolds; and (16) "Issues for Policy Makers" by Ron Sandrey and Grant Scobie.

Agrarian Capitalism: Does Nature Matter?

Agrarian Capitalism in Theory and Practice. *By Susan Archer Mann. Chapel Hill: The University of North Carolina Press, 1990, 221 pages, $29.95 (hardback).*

Reviewed by Ann Marie Vandeman

In the intensively cultivated agricultural valleys of California, Lenin would have found confirmation of his view that the capitalist form of production was developing in agriculture much the same as in industry. But, from the Midwest, one could support the opposite conclusion and argue for the inherent superiority of family-based agricultural production. Agriculture has been organized in many different forms in many regions and time periods in the United States, from the cash grain farms of the Midwest that fit the "traditional" view of the family farm, to the wage labor-dependent factories-in-the-field of central Washington, Oregon, and California, to the sharecropping system so central to post-emancipation agriculture in the Southeast. These widely varying forms of agricultural production exist under different crops, technologies, markets, and social conditions. How do we sort out the influences of each of these factors in determining the form of production, and how do these forms change over time? Mann answers these questions in her particularly creative and intelligent new book.

Sociologists will be familiar with Mann's earlier work on this subject, well known as the Mann-Dickinson thesis. Grounded in classical Marxist theory, it attributes the central role in setting the limits of capitalist development in agriculture to nature. *Agrarian Capitalism* is an extension and further application of this earlier work.

Mann uses U.S. Census of Agriculture data to measure the degree of capitalist development, by type of crop, and the impact of natural obstacles on this development. Her main criticism of her predecessors in the debate on the agrarian question is that they have ignored the unique features of agricultural production as centered in and dependent on natural processes. She avoids reliance on the functionally determinist argument that family farms exist because capitalists prefer them to, and on the Weberian view that family farms survive because of farmers' strong drive for independence. Neither approach explains why agriculture should be organized any differently than industrial production. It is precisely the role of nature that distinguishes agriculture and industry, and that distinguishes Mann's contribution to the debate.

One reason Mann's analysis is particularly appealing is that the point is so obvious. It is "natural" that nature play a part in determining the social organization of agriculture. Wheat cannot be produced in a factory. Mann also explicitly recognizes that natural obstacles to capitalist development are influenced by social conditions and that they change over time. Thus, rather than replacing functional with biological determinism, her analysis is interdisciplinary. If you believe that the social structure of agriculture cannot be understood solely from the viewpoint of economics—or sociology, anthropology, or history for that matter—then you will like the book. I recommend it especially for those of us who tire of the one-dimensional approach that places the market always at the center of the universe.

The trouble with examining reality is that nothing stays constant, as we are so fond of assuming, and this makes her historical analysis of cotton production in the South difficult. At times, this section of the book seems confused, in part because there are so many factors to sort out which influence the social organization of cotton production. Curiously, she chose to focus on a crop that does not confirm her theory in all respects.

Natural obstacles (the length of production time) and market constraints (lack of credit for wage payments), according to Mann, helped prevent adoption of a wage labor system in cotton prior to mechanization. But, for planters, the problem of how to organize production came down to access to and control over labor power. In this context, Mann argues that sharecropping allowed planters to take advantage of unequal power relations within the family. Other writers have overlooked the role of patriarchy in disciplining family labor, including, as she points out, both Chayanov and Weber, whose concept of self-exploitation ignores the significant role of patriarchal relations in family-based production. The book is worth reading for this discussion alone and for her treatment of the role of the State and world market in the eventual replacement of sharecropping by wage labor in cotton.

The analysis is not without problems, however. For example, in attempting to explain the current use of sharecropping in strawberries, she ignores the fact that sharecroppers themselves must hire labor for the harvest. To call this a nonwage form of production is inaccurate. This is true of contract farming as well. And, although she is able to show that the use of wage labor in cotton increased when changes in technology resulted in a more even seasonal distribution of labor requirements, large seasonal peaks in labor demand in the production of many fruits and vegetables do not appear to have obstructed capitalist development in those crops. In some ways, Mann's thesis raises as many questions as it answers.

Vandeman is an agricultural economist with the Resources and Technology Division, ERS.

The book includes an extensive bibliography covering works on the sociology of agriculture, agrarian capitalism, women in agriculture, sharecropping, and the economic and social history of the South that should not be overlooked. *Agrarian Capitalism* is a refreshing and welcome addition to the literature in all of these areas.

Suggestions to Contributors for Submitting Manuscripts to *The Journal of Agricultural Economics Research*

1. SOURCE. Indicate how the material submitted is related to the economic research program of the U.S. Department of Agriculture and its cooperating agencies. State your own connection with the program.
2. CLEARANCE. Obtain any approval required in your own agency or institution before sending your manuscript to one of the editors of *The Journal of Agricultural Economics Research.* Attach a copy of such approval to the manuscript.
3. ORIGINALITY OF MATERIAL. It is our policy to print original material. We consider alternative treatments of material published elsewhere, but such treatments need to differ substantially from the original approach. When submitting your manuscript, identify related material either published or submitted for publication.
4. ABSTRACT. Include an abstract and at least three keywords when you submit your article. The abstract should not exceed 100 words. It should report the major findings of your research.
5. NUMBER OF COPIES. Submit three good copies.
6. TYPING. Double space everything, including abstract, footnotes, and references.
7. FOOTNOTES. Number consecutively throughout the article.
8. REFERENCES. Check all references carefully for accuracy and completeness. Cite references in the text by using underscored numbers in parentheses that correspond to items in the reference section at the end of your article.
9. CHARTS AND OTHER ARTWORK. Use charts sparingly. Keep design as simple as possible. Submit all artwork in draft rather than in final form, accompanied by neatly prepared pages with essential data for replotting.

UNITED STATES DEPARTMENT OF AGRICULTURE
ECONOMIC RESEARCH SERVICE
1301 NEW YORK AVENUE, NW
WASHINGTON, D.C. 20005-4788

BULK RATE
POSTAGE & FEES PAID
USDA
PERMIT NO. G-145